Assessment of Psychometric Invariance of the Wechsler Adult Intelligence Scales

BIRANCHI N. PUHAN

Psychologists often use tests to make diagnosis, select personnel, decide experimental groups, measure dependent behaviour, prove or generate certain hypothesis, etc. without realizing the possibilities of being misguided by these test results. Following certain standard factor analytic models, this book examines the stability of meaning or psychometric invariance of Wechsler's *Adult Intelligence Scales. It seeks to demonstrate that the majority of these tests measure very different behaviours in persons belonging to different age groups.* The author also argues that traditional test reliability and validity have restricted implications and may be treated better under different aspects of psychometric invariance assessment of a test.

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Assessment of Psychometric Invariance of the Wechsler Adult Intelligence Scales

BIRANCHI N. PUHAN
Reader in Psychology
Utkal University

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To Lisa

Foreword

It is difficult to think of researching in psychology without making use of some sort of test or measuring instrument. The researches which appear not to have used any tests in the formal sense only take a different view of testing through logical coding of subject's response. For example, in experimental studies testings are often blended into the methods of investigation.

It is one thing to use a test for psychological researches, making diagnosis, etc. and another thing altogether to research into the test itself. This second group of researches are essentially related to the basic technology of testing which is perhaps the simple definition of psychometrics. The present research report of Dr. Puhan is an example of such works in the area of testing. Readers hoping for simple answers to basic requirements of psychological tests are likely to feel disappointed with this book. It actually presents disturbing evidences that the psychological tests may often measure very different things in different people thus suggesting psychometric non-invariance for those tests. It is like a goldsmith who feels lost on discovering that his weighing machine actually measures weight when selling but temperature while buying metal in the form of hot liquid. Of course this sort of possibility will be quickly detected in physical measures. But Dr. Puhan's report suggests that such possibilities may not be entirely ruled out in psychological tests because it is likely to go unnoticed.

The concept of psychometric invariance is relatively new to the area of psychometrics. Taking any new step is often associated with some amount of risk. In researches, however, taking a new step is likely to end up in significant gain to the area provided it is well designed and neat as the present one. The worth of any work is often judged through its overall implications to the area. The results of the assessment of psychometric invariance of WAIS seems to have interesting implications for the areas such as test reliability and validity. It has actually raised more questions than answering them. It is these questions which would perhaps make this publication popular particularly among researchers in psychology and other disciplines that use psychological tests.

I do not work strictly in the area of testing and measurement. However, I often use tests as much as others do. On reading this manuscript I feel convinced that Dr. Puhan is making a good point through his proposition of the assessment of stability of the meaning of tests which he calls psychometric invariance. Such an assessment is bound to make an impact in the area of testing and test technology.

R. RATH
Professor of Psychology
Utkal University

Preface

Much of the contents of this book is directly drawn from the author's dissertation submitted to the Faculty and Graduate Studies, University of Manitoba, in partial fulfilment of the requirements for Ph.D. degree. This book hopes to introduce the concept of psychometric invariance to the readers through the simplest logic of theoretical and mathematical inferences. A new concept, when introduced to a branch of scientific discipline, needs to be explained with common examples, related with the existing concepts, and elaborated with its full range of implications. The concept of psychometric invariance has been dealt here keeping these obligations in view.

In chapter I the concept of psychometric invariance is defined as merely referring to the structural stability of a measuring instrument or simply a row in the Factor Matrix across any specified dimension against which it is intended to be used. The implications, usability, and overall stability of psychometric invariance in psychometrics have been traced through its relations with other existing requirements of psychological tests, viz., reliability and validity. It is pointed out that the usefulness of psychometric invariance far exceeds those of traditional reliability and validity assessment of a test. In chapter IV it is proposed that reliability and validity assessments of any psychological test be replaced by psychometric invariance assessment. For psychometric invariance assessment simultaneously evaluates reliability and validity of a test in terms of its factor loading components. With regard to the implications of psychometric invariance to the technology of testing it is suggested that this kind of assessment examines whether or not a test perceived in the same manner (or measures the same behavioural traits) when given to subjects belonging to characteristically different groups for which it is meant to be used.

The other objective of this book is to demonstrate the psychometric invariance requirements for a standard psychological test. Wechsler Adult Intelligence Scales (WAIS) were considered fitting for the purpose because most of the test reviewers agree that it is one of the best psychological tests and has almost become a standard against which other adult scales are often validated. The critical descriptions for all the WAIS subscales, the description of the sample, and procedure appear in chapter II. The invariance analyses and their results are given in chapter III. The limitations of the study are mainly related to the sampling procedure and the inadequacies in factor matching procedure. These points and the issues arising therefrom have been elaborated and discussed in chapter IV.

The author is deeply grateful to Dr. M.S. Aftanas for his guidance, supervision, and instigating ideas through discussions and to Dr. J.R. Royce for his valuable comments as external examiner. Most of these ideas and comments have been incorporated in this book. Sincere thanks are also extended to Drs. L.J. Breen, A.W. Pressey, J.H. Whiteley, and A. Bowd for their comments throughout the development of this work.

The author feels a great personal obligation to Dr. R. Rath for his foreword and for getting this book published on behalf of our department and to Dr. B.B. Chatterjee for his help and encouragement during the preparation of the book.

Special acknowledgements are due to my wife, Gopa, for typing the manuscript, many related papers, and most of all for her continued understanding.

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CHAPTER I

Introduction

Balinsky (1941 : 231) is perhaps the first to indicate that the factorial composition of psychological measures changes as a function of age. This suggests that the same test, given to a person of a certain age, would measure different abilities or factors from those when given to a person of a different age. Since then many investigators have suggested the possibility of changes in factorial composition of different measuring instruments particularly in a developmental context (Aftanas, 1966; Anastasi, 1961; Garrett, 1946; Jones, 1959: 721; Lienert & Crott, 1964). It seems that these suggestions have been made to elaborate the implications of the demonstrated changes in factor structures (i.e., factor loadings of factors) across age groups. However, from the measurement point of view the developmental changes in factor contents of a measure need to be investigated beyond what have been implicated in the studies on changes in factor structures across the age groups. After all, the stability or instability of the factor contents of a test across the age groups, for example, does not necessarily depend on the stability or instability of factor structures (Balinsky, 1941).

Recently Aftanas (1971a) has proposed a measurement approach in which he calls upon investigators to examine the stability of factor composition of measuring instruments under conditions of change; one such condition being developmental. From the measurement point of view it is therefore important to demonstrate the stability of factor contents of a measuring instrument in the developmental context before it is given to persons of different age groups. If a certain test is found to have different factorial compositions across age groups it indicates that the nature of the test (in terms of what it measures) changes in the developmental context and therefore is an inappropriate measure in that context.

The subject-matter most researched within the area of measurement in the developmental context is the measurement of intelligence and WAIS subscales in particular. The present study therefore intends to evaluate the stability (invariance) of psychometric components of the WAIS subscales across two selected adult age groups.

REVIEW OF THE LITERATURE

Development of Intelligence During Childhood

One of the earlier developmental studies of intelligence was that of Gesell (1928). He advocated a logarithmic function between age and intelligence, thus suggesting a very rapid growth of intelligence particularly during the childhood period. A similar theory was formulated by Terman (1916) who assumed a linear (one-to-one) relationship between age and intelligence. According to him, such a trend continues until the age between 16 and 18 and then reaches its peak (maximum growth). On the other hand, Thorndike, Bregman, Cobb, and Woodyard (1927) proposed a "parabolic function" of intellectual growth. According to this theory, a child acquires about one-half of his adult mental growth by the age of three. The results of all these studies were contradicted by those of Thurstone and Ackerson (1929). They have found that intelligence grows rapidly during the first nine or ten years, passes through a period of almost no growth around age eleven, and then grows slowly until it reaches the peak at the age of eighteen.

The reasons for differential findings relating to the developmental changes of intelligence are summarized by Goodenough (1954 : 477-478). She has attributed these differences mainly to the dissimilarities in test contents or statistical procedures used in deriving the developmental functions of intelligence or both.

It appears that most of the initial studies concerning the development of intelligence were limited to the childhood period which only represents a part of the entire life-span. Perhaps the lack of adequate adult intelligence scales during the time was responsible for such incomplete descriptions of the development of intelligence.

Development of Intelligence During Adult Life-Span

The construction of many adult intelligence scales, particularly those of Wechsler (i.e., Wechsler-Bellevue Intelligence Scales and Wechsler Adult Intelligence Scales), seems to have created wider opportunities for studies attempting to describe the developmental functions of intelligence for the entire life-span. Among these, Wechsler's (1958) results are considered to be most representative by many critics (e.g., Bromley, 1966; Butcher, 1968; Guilford, 1967; Jones, 1959).

Wechsler (1958 : 199-213) has reported that intelligence based on the total score on the WAIS attains its growth peak at the age of twenty-five and starts declining after the age of thirty. The rate of decline after this age is almost linear up to the age of seventy-five. He has also compared the developmental functions of his verbal and performance scales and found that the former showed less rapid decline than the latter. Wechsler (1958) has further reported that the scales showing the most rapid decline were the Digit Symbol, Picture Completion, Picture Arrangement, and Block Design and the scales showing the least rapid decline were the Information, Vocabulary, and Comprehension. Most of the cross-sectional studies on W-B I and WAIS seem to agree with Wechsler's results (Doppelt & Wallace, 1955; Corsini & Fassett, 1953; Fox & Birren, 1949; Heston & Cannell, 1941; Riegel, 1958). On the other hand, most of the longitudinal studies on the WAIS or related tests tend to show a general improvement until at least early forties for performance scales and late sixties for verbal scales (Bayley, 1955; Owens, 1966; Welford, 1958).

The results of developmental studies of intelligence would seem to have questionable scientific significance because of some inherent methodological and theoretical problems. All these studies have adopted either cross-sectional or longitudinal research designs, the validity of which is repeatedly challenged (Baltes, 1968; Schaie, 1965; Schaie & Strother, 1968a, 1968b) and still under scrutiny (Schaie, 1970). In a cross-sectional design the investigator attempts to gather developmental information by selecting age groups of interest and comparing the resultant dependent variables. But Schaie (1965) has objected to such a practice on the basis that the observed results, in this case, might represent a confounding effect of age and cohort (generational) factors. In the longitudinal design, a single group of subjects are studied at different ages of interest. Here also the observed results are likely to represent a confounding effect of age and time of measurement (environmental change) factors (Schaie, 1965).

The other difficulty with these studies (i.e., Bayley, 1955; Corsini & Fassett, 1953; Fox & Birren, 1949; Heston & Cannell, 1941; Owens 1966; Wechsler, 1958) seems to be a theoretical one. According to Aftanas (1971b), all these studies are primarily oriented to describe the developmental changes of psychological construct(s) as supposedly measured by a single test and therefore reflect a "construct approach". In other words, a single test study, investigating the function of the WAIS comprehension scale across age groups, is essentially concerned with the developmental function of the psychological "construct of comprehension". However, from the measurement point of view, this approach is not informative because it is contrary to the basic model of a test variance.

A Model of Test Variance

According to Guilford (1948) the total variance of a test can be subdivided into the following additive component variances:

1. A number of common factors (common in the sense that they appear in more than one measure).
2. A possible specific factor (a factor that appears consistently in the same variable from time to time but not in other variables).
3. Error variance.

In order to understand the basic postulates of Guilford it is important to define the term "factor". Factors are described as hypothetical constructs (Harman, 1960), or convenient classificatory conceptualizations (Anastasi, 1938) which are considered "real" (Thurstone, 1947) in terms of individual's functional manifestations. According to Royce (1963), factors basically represent theoretical or psychological constructs. He has also described them as dimensions, determinants, functional unities, parameters, and taxonomic categories. The term "factor" has also been used to mean independent abilities such as Primary Mental Abilities (Thurstone, 1938) or "distinct ability factors" (French, Ekstrom & Price, 1963; Guilford, 1959, 1967). It should be pointed out that an ability by itself does not necessarily mean a factor unless it is considered to be (at least theoretically) a unique, an independent, or a primary function. At the empirical level these factors are determined by factor analysis which refers to a mathematical technique to reduce a given set of data to a simpler form without losing any information inherent in the original data (Harman, 1960). The final step of this data-reduction process is to obtain a Factor Matrix (see Table 1).

TABLE 1 : **Factor Matrix***

	Factor					
	1	2	.	.	.	r
1	a_{11}	a_{12}	...	...	...	a_{1r}
2	a_{21}	a_{22}	...	...	...	a_{2r}
.	...	...	...	...	...	...
.	...	...	...	...	...	...
.	...	...	..	...	...	...
j	a_{j1}	a_{j2}	...	...	...	a_{jr}

Note : The entries in the Factor Matrix (a_{jr}) refer to the factor loadings of test j on factor r and express the extent of relationship between tests and factors.

*Puhan (1975).

According to Guilford (1948), the total variance of a test could be expressed mathematically by the following equation.

$$\sigma^2_j = a^2_{j1} + a^2_{j2} + \ldots + a^2_{jr} + s^2_j + e^2_j = 1.00\text{[1]} \qquad (1)$$

in which

---

[1] Keeping the underlying meanings or definitions intact, some of the notations which appeared in the original sources were changed in order to make the equations comparable and most importantly to develop a single equation outlining the relationships among various estimates of a test.

σ^2_j = the total variance of test j,
a^2 = the proportion of variance contributed by r number of common factors (common in the sense that they appear in more than one measure) to test j,
s^2 = the proportion of variance contributed by a specific factor (a factor that appears consistently in the same variable from time to time but not in the other variables) to test j, and
e^2 = the proportion of variance in test j contributed by errors due to sampling, conditions of testing, changes within individuals, etc.

Thurstone (1947) and Harman (1960) have defined the sum of the common variance as communality which could be expressed by the equation :

$$h^2_j = a^2_{j1} + a^2_{j2} + \ldots + a^2_{jr} \tag{2}$$

in which

h^2_j = the communality estimate of test j.

Guilford (1948) has further indicated that the proportion of non-error variance of a test or its reliability can be described by the equation:

$$r_{jj} = a^2_{j1} + a^2_{j2} + \ldots + a^2_{jr} + s^2_j = 1 - e^2_j \tag{3}$$

A relative description of all the ideas expressed in the preceding formulations could be summarized by a single equation :

$$\sigma^2_j \gtrsim a^2_{j1} + a^2_{j2} + \ldots + a^2_{jr} + s^2_j = 1 - e^2_j = r_{jj} > h^2_j \tag{4}$$

Equation 4 suggests the following facts:

1. that more factors than one account for the total variance of a test,
2. that communality represents a lower bound of the total variance and reliability estimate of a test, and

3. that in an ideal (error- and specific variance-free) situation, total variance, reliability, and communality of a test should be the same.

A Model of Factor Variance

It could be pointed out that a similar factor analytic model of a test variance could be used to describe the total variance of a factor differing only in intent (direction). For example, the contents of a factor variance could be viewed as constituting an additive function of several tests as expressed by the equation:

$$\sigma^2{}_r = a^2{}_{1r} + a^2{}_{2r} + \ldots + a^2{}_{jr} + e^2{}_r = \mathrm{ev}_r \qquad (5)$$

in which

$\sigma^2{}_r$ = the total variance of a factor r,
$a^2{}_2$ = the proportion of variance contributed by j number of tests,
e^2 = the proportion of error variance (in this case errors associated with analytical techniques), and
ev_r = eigen value of factor r.

The approach presented in eq. 5 has in fact served as the basis for Nesselroade's (1970) model for developmental studies. Following this approach, studies have attempted to examine the stability of the structure of a psychological factor down the column in a Factor Matrix (i.e., $a_{1r}, a_{2r}, \ldots, a_{jr}$ in Table 1) for various developmental, cultural, or clinical groups (Puhan, 1975a). This approach is also indicative in a vast number of multivariate studies on Wechsler's adult scales in developmental, behavioural, and cultural contexts (i.e., Balinsky, 1941; Berger, Bernstein, Klein & Lucas, 1964; Birren 1952; Green & Berkowitz, 1964; Maxwell, 1961; Puhan, 1978a; O'Neil, 1962; Radcliffe, 1966; Riegel & Riegel, 1962; Shaw, 1967; Sprague & Quary, 1966; Weiner, 1964; Zimmerman, Whitemyre & Fields, 1970) most of which are reviewed and discussed by Reinert (1970). Of these, the developmental changes in factor structures of Wechsler's scales have received considerable attention in the past decades.

Multivariate Developmental Studies of Intelligence

Balinsky's (1941) study was the first multivariate investigation of the development of intelligence using one of the Wechsler's scales (i.e., W-B I). Obtaining all his data from the standardization sample, he has factor analysed the correlation matrices for six age groups (i.e., 9, 12, 15, 25-29, 35-44 & 50-59). He has then compared the factor structures for these groups and found an increase in the number of factors extracted between 9 and 25-29, followed by a decrease in the 35-44 and 50-59 age groups. On the basis of his findings, Balinsky has suggested that there is a "tendency toward greater specification" from age 9 to age 25-29 and thereafter an apparent reorganization to the complexity which he has described as "flexible".

The findings of Balinsky have provided supporting evidence for the differentiation theory of Garrett (1946). According to this theory, all psychological abilities which are found by factor analysis develop through a differentiation process that starts from a single, general (g) intellectual ability (Spearman, 1904, 1927) in early childhood. Based on the theoretical formulations of Garrett and the empirical findings of Balinsky, several studies have attempted to evaluate the changing nature of the factor structures of Wechsler's scales in a developmental context.

Cohen (1957), using a portion of the WAIS standardization data (Wechsler, 1955; Doppelt & Wallace, 1955), has factor analysed the WAIS subscores for four adult age groups (i.e., 18-19, 25-34, 45-54 & 60-75+) and found three major factors, i.e., Verbal Comprehension, Perceptual Organization, and Memory. Based on his results, Cohen has suggested that the development of intellectual factors is essentially invariant throughout the life-span with the exception of the 60-75+ age group. For this group the memory factor has been distributed over several tests along with Arithmetic and Digit Span. In addition, Cohen has noted a strong general factor operating for all the age groups he has studied which has contradicted the differentiation hypothesis (Garrett, 1946) and its earlier established evidence (Balinsky, 1941).

Using different factor analytic techniques, Berger *et al.* (1964) have reanalysed Cohen's data. One of the basic purposes of this study was to gather information on age-functional changes of the WAIS factors in the developmental context. The investigators have obtained unadjusted correlation coefficients (Burt, 1941 : 343) for all possible age pairs and reported uniformity in the Verbal Comprehension and Perceptual Organization factor patterns across the age groups. However, the third factor (i.e., Memory) was found only in the 25-34 and 45-54 age groups and not in the 18-19 and 60-75+ age groups.

The overall findings of Berger *et al.* (1964) and Cohen (1957) were replicated on brain damaged (Reed & Fitzhugh, 1967) and normal (Savage & Bolton, 1968) subjects. But a subsequent reanalysis (i.e., Radcliffe, 1966) of Cohen's data has suggested that the WAIS factor structures become increasingly complex as a function of chronological age (e.g., two, three, and five factors for Cohen's first, second, and third age groups). This study has provided strong support for the differentiation hypothesis. A somewhat modified version of the differentiation hypothesis has been proposed by Green and Berkowitz (1964) who have found a "general-to-specific-to-general" function of the WAIS factor structures for various age groups ranging from under-29 to over-65. They, too, have found that a Memory factor was evident in all but the under-29 age groups which was earlier reported by Balinsky (1941).

A part of Cohen's (1957) results were also contradicted by Birren (1952) who found a different set of factors (i.e., Verbal Comprehension, Closure, Rote Memory, and Induction) for W-B subscales. However, the results of Birren's study seem to have fewer implications in a developmental context because the data are based only on subjects between 60 and 74 years of age. A similar restricted sample was later studied by Riegel and Riegel (1962). The results of this study, though limited by the same drawback as that of Birren's (1952), are significant for their cross-cultural implications. The investigators have factor analysed the German version of the WAIS (i.e., Hamburg-Wechsler-Intelligenz-Tests fur Erwachsene: Riegel & Riegel, 1959) and found no appreciable difference in factor structures for German and American cultures. However, reanalysing Cohen's (1957) data, Riegel and Riegel (1962) have found age-functional differences in WAIS factor structure. A similar concern was expressed by Maxwell (1961) who found somewhat different factors (i.e., Verbal Comprehension, Space Performance, and

Education of Conceptual Relations) of WAIS subscales for 60-64, 65-69, 70-74, and 75+ age groups.

A review relating to the developmental changes of the WAIS factors has indicated that there have been some studies partly supporting the differentiation hypothesis (Balinsky, 1941; Radcliffe, 1966) whereas others have rejected it in part (Berger *et al.*, 1964; Birren, 1952; Cohen, 1952a, 1956, 1957; Maxwell, 1961) or entirely (Weiner, 1964). One apparent reason for such differential findings seems to be different analytical techniques of data analysis used by the investigators. For example, in initial extractions of factor structures of the WAIS subscales Balinsky (1941), Berger *et al.* (1964), and Cohen (1952a, 1957) have used Thurstone's (1947) centroid method whereas Maxwell (1961), Riegel & Riegel (1962), and Savage & Bolton (1968) have used Hotelling's (1933) principal components solutions. The subsequent rotations in these studies even differ greatly ranging from Thurstone's (1947) graphic rotation in Maxwell's (1961) to Carroll's (1958) mathematically more complex oblique rotation in the Berger *et al.* (1964) study. In the midst of all these differences in analytical procedures and subsequent results, however, one fact is clearly evident. The psychological factors measured by the W-B I or WAIS undergo considerable changes throughout the adult life-span.

The changing nature of the intellectual factors seems to have reinforced the previous investigators to see whether or not the configuration of the basic factorial components of factors (patterns of factor loadings of columns in the Factor Matrix) remains stable or invariant for various age groups. An invariance such as this is traditionally known as "factorial invariance" (Thurstone, 1947 : 361). However, from the measurement point of view an assessment of factorial invariance is perhaps less informative because its concern has never been nor does it answer the question whether or not the basic psychometric descriptions of a measuring instrument remain stable in a developmental context.

THE ASSESSMENT OF PSYCHOMETRIC INVARIANCE

In contrast to the factorial invariance, Aftanas (1971a) has proposed the concept of psychometric invariance which calls upon investigators to see whether or not the configuration of the basic psychometric descriptions associated with a measure remains invariant under the conditions of change; some such conditions being cultural, behavioural, developmental, time of measurement, etc. According to Puhan (1975a), psychometric invariance refers to the structural stability of a measuring instrument or simply of a row in the Factor Matrix (i.e., a_{j1}, a_{j2}, $a_{j3}, \ldots, a_{jr}$ in Table 1) across any specified dimension (i.e., developmental, cultural or otherwise) against which it is intended to be used. It is further argued (Aftanas, 1971a; Puhan, 1975a, 1975b, 1978b) that such an evaluation represents a measurement approach because it is primarily concerned with the stability of a measuring instrument in terms of its variance components under the conditions of change. From a measurement point of view it would seem that a developmental comparison of performances on a certain test, for example, would be meaningful and valid if, and only if, the basic psychometric descriptions of that test could be demonstrated as invariant across the age groups that are being compared. Therefore the proposed psychometric invariance is basically concerned with the diagnostic utility or appropriateness of a measure in the context it is being used – developmental, cultural, etc.

The inherent relationship between the concept of psychometric invariance with the concepts of reliability and validity seems to be another reason why a psychometric invariance assessment is considered representing a measurement approach. According to Aftanas (1971a), if it could be demonstrated that the basic psychometric components of a test remain the same in two successive administrations then the test could be considered reliable. This would not only represent a special kind of test-retest reliability but also an evaluation of psychometric invariance *across time*. A special kind of parallel form of reliability could also be determined, if it could be demonstrated that the basic psychometric components of a test remain stable across similar or equivalent tests. This would perhaps represent an assessment of psychometric invariance *across tests*.

On the other hand, if it could be demonstrated that the major sources of variability of a test are identified with the construct(s) that are being measured, then the test could be considered valid (Aftanas, 1971a). Furthermore, if it could be demonstrated that the major sources of variability of a test are identified with the construct(s) that are being measured and consistently so across age, sex, cultural, behavioural groups, etc., then the test could be considered as psychometrically valid. This would represent an evaluation of psychometric invariance *across groups.*

REINTERPRETATION OF PREVIOUS FINDINGS

The lack of various kinds of psychometric invariance of WAIS seems to be suggested in many of the factor analytic studies we have discussed earlier. A comparison of the factor loading configurations of the Information scale from Riegel and Riegel's (1962) findings would indicate that cultural psychometric invariance was never achieved for this scale (see Appendix A). In a recent article, Puhan (1978c) has more fully elaborated the meaning of cultural psychometric invariance and its implications.

The lack of psychometric invariance of WAIS Vocabulary and Arithmetic subscales has already been suggested in the developmental context (Aftanas, 1971b). Based on the rearranged tables of Cohen (1957) and Berger *et al.* (1964), the present investigator has noted similar results particularly for WAIS Information (see Appendix B) and Digit Span (see Appendix C) subscales.

These examples suggest that psychometric invariance of some of the WAIS subscales has never been demonstrated in a developmental context and they often tend to measure different things (factors) in different groups.

STATEMENT OF THE PROBLEM

A statement implying the lack of psychometric invariance of the WAIS would not be completely appropriate at this point because almost all the studies which suggest such a possibility (i.e., Berger *et. al.*, 1964; Cohen, 1957; Riegel & Riegel, 1962) are based partly or fully on the original standardization sample of the WAIS which was collected some time ago (Wechsler, 1955; Doppelt & Wallace, 1955). Besides, these studies have failed to account for a satisfactory amount of reliable variance

(r_{jj}) for different WAIS. For example, an examination of h^2s in Berger *et al.* (1964) and Cohen's (1957) results revealed that all these values were less than .40 except for one (i.e., Vocabulary in Berger *et al.*, 1964). Further, all these h^2s were very low with respect to their corresponding reliability estimates (r_{jj}) which are in the neighbourhood of .80 (see Appendix D). Ideally the h^2 and the r_{jj} of a test should be the same. In a practical situation, however, these two estimates of a test might differ only by a small margin owing to the contributions of the specific variances (s^2_j) to the total variance of that test (see eq. 4).

One way to approach this problem has already been indicated by Davis (1956). In Davis' study, the W-B I subscales were factor analysed along with thirteen reference (related) variables for a single group. He then calculated the total percentage of variance (h^2) of each of the W-B scales ascribable to the interpretable factors. An examination of these h^2s indicated that six of the eleven h^2s were more than .40 which suggested that more than 40% of the total variance of each of these six W-B I scales was accounted for by different sources of variance (interpretable factors). Further, some of these h^2s (i.e., for Information and Arithmetic subtests) were close to the reliability estimates of the corresponding scales (see Appendix D). Therefore, it was felt that more "reference tests" (Davis, 1956) or "marker variables" (Cattell, 1952 : 238; Comrey, 1973 : 190; Puhan, 1978d, 1978e) should be included and factor analysed along with the WAIS to raise the h^2s of its subscales and thereby reduce the difference between the h^2 and r_{jj} of each of the WAIS. Only then would an evaluation of psychometric stability of a measure be more meaningful. Therefore, it was proposed that several reference or marker tests of known factor content (i.e., eight subscales of Differential Aptitude Tests, four subscales of Culture Fair Intelligence Tests, and Advanced Progressive Matrices) be included in the present investigation to assess the psychometric invariance of the WAIS subscales.

The purpose of the present study was, therefore, to assess the psychometric invariance of the WAIS subscales in a developmental context under the conditions that should lead to a greater proportion of accountable variance for the subscales. Such an assessment was considered important in determining the diagnostic utility or appropriateness of the WAIS subscales across adult age groups.

The selection of the WAIS for the present study was based on its merits as a valid indicant of adult intelligence, its efficiency as a diagnostic instrument for certain pathological cases, and its overwhelming popularity among test users. Besides, the WAIS is not only considered as "the best test of adult intelligence" (Burstein, 1972; Lyman, 1972) but it has also become a "standard" against which other adult tests are often compared (Bayley, 1959; Guertin, 1959). Therefore, the assessment of psychometric invariance of the WAIS would perhaps benefit a vast number of users – those who administer it and those who refer to it as a standard.

CHAPTER II

Method

It has been said in the preceding chapter that the present study is based on a measurement approach in that it intends to find out whether or not the meaning of a certain measuring instrument remains the same in a developmental context. Many investigators (Balinsky, 1941; Baltes, 1968; Nesselroade, 1970) have argued for significant structural changes associated with age. It is, therefore, very unlikely that psychometric invariance of the WAIS would exist across the entire life-span. Under this situation the best approach would be to demonstrate the boundary conditions (e.g., certain age or cultural groups) of psychometric invariance. Thus, a most appropriate and informative study of psychometric invariance of the WAIS in a developmental context should investigate all possible adult age groups to determine these boundary conditions. As a starting point, therefore, the present study included only two age groups (viz., 18-19 and 25-33) for which the lack of psychometric stability of some of the WAIS subscales was indicated in Berger *et al.* (1964) and Cohen's (1957) studies. It could, however, be pointed out that should the WAIS be found to be psychometrically stable or otherwise across the present age groups, a generalization implying the same to the entire adult life-span would not be necessarily warranted. Rather, the implications of the results of the present study would only be limited to the age groups under investigation.

Furthermore, a cross-sectional design was considered to be most appropriate for the present study. As pointed out by Aftanas (1971b), the possible cohort-related errors in a cross-sectional design (Schaie, 1965; Baltes, 1968) are only applicable to a construct-oriented study where developmental descriptions of a psychological factor are of utmost concern. In contrast, the present study is based on a measurement approach where the basic concern is to see whether or not the meanings of certain measuring instruments remain the same across the age groups at a given point in time. In terms of practical implications, the results of such an assessment would indicate whether or not the instruments under investigation could be used to compare two or more individuals of different ages at a given point in time.

SUBJECTS

A total of 200 subjects (i.e., 100 in each group) were tested for the present study. All the subjects of the 18-19 age group and 50 of the 25-34 age group were drawn from introductory psychology classes of the University of Manitoba who participated in the study as a part of their course requirements. Forty subjects of the 25-34 age group were drawn from introductory psychology classes of the evening and summer school of the same university. These subjects participated in the present study in lieu of a term paper required by their respective courses. The remaining 10 subjects of the 25-34 age group were volunteers who participated in the study to get some general feedback with regard to their performance on various ability tests. All these volunteers were high school graduates. In each group the subjects were evenly divided with respect to sex. Also care was taken to avoid unequal distribution of subjects of different ages within the 25-34 age group. For example, there were 35 subjects in each of the age ranges of 25-27 and 28-30 and 30 subjects in the age range of 31-34. All the subjects of the present study were Canadian citizens or had lived in Canada for at least ten years at the time of testing.

PROCEDURE

All the subjects were tested on the Wechsler Adult Intelligence Scale (Wechsler, 1955), Differential Aptitude Tests (Bennett, Seashore & Wesman, 1966), Culture Fair Intelligence Tests (Cattell & Cattell, 1959), and Advanced Progressive Matrices (Raven, 1947). The details of the testing procedure are outlined in Table 2.

In the begining of the first session, all the subjects were briefed about the general nature and objectives of the study.

TABLE 2 : Description of the Testing Procedure

Testing Session	Name of Test	Testing Condition
I	WAIS (all the 11 subscales)	Individual
II	DAT (the first 4 subscales)	Group of 10-15
III	DAT (the last 4 subscales)	Group of 10-15
IV	CFIT (all the 4 subscales) and PM-A	Group of 6-10

They were assured that their test results would not be shown to anybody or published individually. They were further told that with their permission the test results could be obtained by an authorized agency or a practitioner for the purpose of vocational or clinical evaluation. The volunteers of the 25-34 age group were promised general feedback with regard to their performance on the tests.

All tests were administered in strict accordance with the instructions provided by the respective test manuals. The instructions for all group tests were read out while the subjects were asked to read them simultaneously with the experimenter. These instructions appeared on the front page of each of the test booklets. Wherever applicable, the examples of the test contents and various approaches to solve them were demonstrated on the blackboard. Testing was carried out at the University of Manitoba under a standardized set of testing conditions. For all subjects there was a minimum of five days' interval between their successive testing sessions. In no case did the interval exceed three weeks.

The following are the brief descriptions of the measures used in the present study. The details of the nature of administration, time limit, scoring procedures, etc. are cited in Appendix E.

DESCRIPTIONS OF THE MAIN VARIABLES

Wechsler Adult Intelligence Scales (WAIS)

The WAIS (Wechsler, 1955) is a revision and restandardization of Form I of the Wechsler-Bellevue (W-B) Intelligence Scale. It was standardized on a carefully selected stratified sample of 2,175 Americans representing different ages, sexes, occupations, geographical locations, rural-urban settings, educational levels, and racial backgrounds. An additional sample of 475 subjects beyond 60 years of age was also included in the standardization of the WAIS (Doppelt & Wallace, 1955).

The WAIS consists of six verbal (viz., Information, Comprehension, Arithmetic, Digit Span, Similarities, and Vocabulary) and five performance (viz., Digit Symbol, Picture Completion, Block Design, Picture Arrangement, and Object Assembly) subtests. The following are the brief descriptions of the nature of WAIS subscales.

Test 1. Information (Inf)

The Information subtest of the WAIS consists of items seeking a wide variety of information that an average adult with average opportunity may be able to acquire for himself. For example, "What does rubber come from?". Some of the questions of the Information test were changed to suit the Canadian culture. For example, "What is the height of the average Canadian woman?", "How far is it from Montreal to Paris?", etc. This test contains 29 items which were selected from a much larger list on the basis of incidence of success and failure of various groups of individuals of known intelligence levels. An item was considered good if it demonstrated increasing frequency of success with high intellectual level (Wechsler, 1958).

Test 2. Comprehension (Comp)

The questions included in the Comprehension scale are such that an average adult may have had an occasion to answer for himself at some time or heard being discussed by others. For example, "Why should we pay taxes?". According to Matarazzo (1972), success on this test seemingly depends on the possession of a certain amount of practical information and a general ability to evaluate one's past experience.

Test 3. Arithmetic (Arith)

The Arithmetic test consists of 14 items which require the subject to add, subtract, multiply, divide, or perform any two or more of these functions without any special aid. The computation skills needed to solve most of these problems are not beyond those taught in the grade school or what an average adult would acquire by himself in the course of day-to-day interactions with various persons or situations.

Test 4. Similarities (Sim)

The Similarities test of the WAIS consists of 13 items. In this test the subject is asked to tell in what way certain things or incidents or ideas are alike. For example, the subject is asked such questions as "In what way are an orange and a banana alike?". By answering such questions the subject supposedly manifests his ability to perceive the analogies (common elements) between two concepts (Wechsler, 1958).

Test 5. Digit Span (D Sp)

The Digit Span of the WAIS consists of a series of digits of different size. These series are orally presented to the subject who is required to repeat them either in the same order (Digit Forward) or in the reverse order (Digit Backward). Though each digit series has a parallel series, the second one is used only when the subject fails to pass the first.

Test 6. Vocabulary (Voc)

The Vocabulary Scale of the WAIS consists of 40 words which are orally as well as visually presented to the subject. The subject is required to express verbally the dictionary meaning of these words. In this test any recognized meaning is acceptable, and there is no penalty for elegance of language. Differential scoring of subject's response is recommended by Wechsler on the basis of the quality of response. For example, if a subject defines a "slice" as "to cut" he receives one point. But if he defines it as "a piece", it earns him two points.

Test 7. Digit Symbol (D Sy)

The Digit Symbol of the WAIS consists of unfilled squares for different digits and the subject is asked to fill them out by symbols representing digits which are provided. The subject is given a few practice trials to familiarize himself with the nature of the work and then is allowed to work for 90 seconds.

Test 8. Picture Completion (PC)

The Picture Completion test of the WAIS battery requires the subject to discover and name the missing part of incompletely drawn pictures. In this test the subject is presented with an incomplete picture (e.g., a man minus his left little finger or a car minus her door handles) and asked to indicate the most apparent missing part. Many studies (Cohen, 1956, 1957; Berger *et al.*, 1964; Green & Berkowitz, 1964) have indicated that the Picture Completion test measures individual's basic perceptual and conceptual abilities so far as these are involved in the visual recognition and identification of familiar objects and forms. It is also pointed out by both Matarazzo (1972) and Wechsler (1958) that to be able to see the missing part, the subject must appreciate that part in terms of its absolute importance to the structural and/or functional nature of the whole picture.

Test 9. Block Design (BD)

The Block Design test is basically similar to that employed by the Kohs' Test (1923), though its content has been modified to a considerable degree. The original Kohs' Test included figures made up of red, yellow, blue, and white whereas the Block Design of the WAIS permits different patterns of red and white only. According to Wechsler (1958), this modification is necessary to eliminate the possible influence of the colour factor, and to equate more nearly the amount of turning required by the subject for finding the faces of the blocks appropriate to the design.

The Block Design test of the WAIS consists of 10 designs and nine blocks each of which is painted red, or white, or one-half red and one-half white. In this test the subject is given a certain number of blocks and is shown a pattern. The subject then assembles the blocks to make it identical to the pattern shown to him.

Test 10. Picture Arrangement (PA)

The Picture Arrangement test of the WAIS is very similar to the tests developed by DeCroly (1914), Yerkes (1921), and Cornell and Coxe (1934). The items of this test consist of a series of picture cards which are presented to the subject in a disarranged order. The subject then is asked to put these cards together in the right order so that they make a sensible story. There are eight sets of pictures in this test which were selected on the basis of interest of content, appealing quality to the subject, and ease of scoring.

According to Wechsler (1958), the Picture Arrangement test of the WAIS is an effective measure of a subject's ability to comprehend and coordinate a total situation. For this, the subject must understand the whole, and must get an idea of the story before he could arrange them in proper order. Matarazzo (1972) has pointed out that the understanding of these situations corresponds to what some authors (i.e., Schill, Kahn & Muehleman, 1968a, 1968b; and Jones, 1959 : 719) have referred to as "social intelligence".

Test 11. Object Assembly (OA)

The Object Assembly test of the WAIS consists of four-figure form-boards which, when assembled, form different familiar objects. Some of the items of this test (i.e., Manikin and Profile) have been borrowed from the Pintner-Paterson Scale (Pintner & Paterson, 1917) and modified by the author. The other two items (i.e., Hand and Elephant) are entirely new.

According to Wechsler, a subject could attempt to solve the problems of the Object Assembly scale in three different ways. First, the subject could have an immediate perception of the whole, accompanied by a critical understanding of the relation of the individual parts. A second type of response is that of rapid recognition of the whole but with imperfect understanding of the relations between the parts. Finally, it is also possible that the subject may begin with a complete failure to understand the total situation but arrives at the solution by trial-and-error.

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The WAIS manual (Wechsler, 1955) provides equivalent-form reliability coefficients for Digit Span and Digit Symbol and split-half reliability coefficients for the rest of the subscales. These subtest reliability coefficients ranged from a few in the .60 for Picture Arrangement and Object Assembly to as high as .96 for Vocabularly.

The WAIS manual itself (Wechsler, 1955) contains no validity data though Wechsler's subsequent publication (1958) covers several aspects of the validity of the WAIS. The reports of the validity data on the WAIS have been accumulating since it came to existence. A review of these would be unnecessary because most of them are reviewed elsewhere (Matarazzo, 1972 : ch.12). Based on the results of these studies, the validity of the WAIS seems to be less questionable. Recently, Burstein (1972) and Lyman (1972) have insisted that the WAIS is still the "best test of adult intelligence". In some earlier reviews, Bayley (1959) and Guertin (1959) have concluded that the "WAIS has become a standard against which other adult tests are often compared".

DESCRIPTIONS OF THE MARKER VARIABLES

One of the basic objectives of the present study was to manipulate a factor analytic situation which would provide greater accountable variance (h^2s) for each of the WAIS subscales. In accordance with the theoretical formulations of Cattell (1952 : 238), Comrey (1973 : 190) and the empirical findings of Davis (1956), many marker variables or related measures were searched to bring about such a condition. Finally, the subscales of the Differential Aptitude Tests, Advanced Progressive Matrices, and subscales of Culture Fair Intelligence Test were included as marker variables on the basis of their similarities and seemingly differences with the hypothesized factors of WAIS subscales.

Differential Aptitude Tests (DAT)

The DAT developed by Bennett, Seashore, and Wesman (1947) was considerably revised lately (Bennett, Seashore & Wesman, 1966) to provide an integrated and well-standardized procedure for measuring the abilities of school students for the purpose of vocational guidance. This test consists of eight subscales viz., Verbal Reasoning, Space Relations, Language Usage – Spelling, and Language Usage – Grammar, which are supposedly pure measures of different abilities.

There have been conflicting reports with regard to the assumption of factor purity of the Differential Aptitude Tests. Merwin (1972) has indicated that the DAT consists of a series of "relatively independent" scales. However, on the basis of the results of a factor analytic study, Quereshi (1972) has questioned the assumption of factor purity of most of the DAT scales. He has found that except for Clerical Speed and Accuracy and Language Usage – Spelling, all the DAT scales are factorially complex (i.e., accounted for by more than one factor). He has also found a number of scales (i.e., Verbal Reasoning, Language Usage – Spelling, and Language Usage – Grammar) with equally high loadings on the same factor which indicated an undue redundancy of DAT measures.

Test 12. Verbal Reasoning (VR)

The Verbal Reasoning test is a measure of ability to understand concepts framed in words and ability to generalize abstractly rather than simple vocabulary recognition. Therefore it includes many "analogy-type" items which are drawn from a wide range of disciplines (i.e., history, geography, literature, science, etc.). The following is a typical example of the items included in this test.

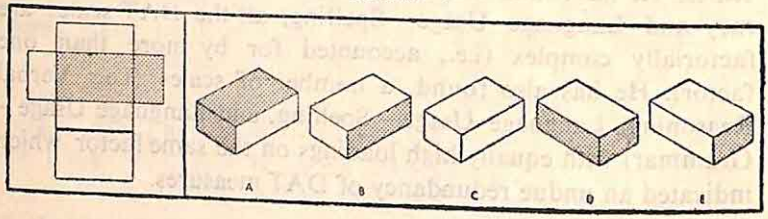
______is to water as eat is to______
1. Continue 2. Drink 3. Foot 4. Girl
A. Drive B. Enemy C. Food D. Industry

The subject is instructed to find a word from the first row for the first blank and a word from the second row for the second blank. The Verbal Reasoning test attempts to measure the subject's understanding of various concepts and verbal relations.

Test 13. Space Relations (SR)

The Space Relations test of the DAT is a measure of ones' ability to deal with concrete materials through visualization and ability to imagine how an object would appear if rotated in a given way. The test also reflects the ability to manipulate things mentally in order to create a structure in one's mind from a plan. The test consists of forty patterns which can be folded into figures. For each pattern five figures are provided. The subject is asked to decide which of these five figures can be made out of the pattern shown. Diagram 1 is an example of the Space Relations Scale.

DIAGRAM 1



According to the authors of the test (Bennett *et al.*, 1966), this test is important in evaluating a person's ability to think in spatial terms.

Test 14. Clerical Speed and Accuracy (CSA)

The Clerical Speed and Accuracy test of the DAT battery is intended to measure one's speed of response in a simple perceptual task. In this test the subject first looks at the combination of letter and digit which is underlined in the test booklet, then bears it in mind while seeking the same combination in a group of similar combinations on the answer sheet which he underlines. The following are examples of the items included in this test.

TEST ITEMS	SAMPLE OF ANSWER SHEET
1. nv nx xn vx xv	1. xn xv nx vx nv
2. bl dl ld lb bd	2. bl ld lb dl bd
3. ar au ur ra ru	3. ra ur ar ru au
4. wu vu vw wv uw	4. vw vu wv wu uw
5. wm um mu wu mw	5. wu wm mu mw um

According to the test authors (Bennett *et al.*, 1966), the items of the CSA test measure the subject's speed of perception, momentary retention, and speed of response. There are two parts of this test, each consisting of 100 items. Only the second part of the CSA is scored.

Test 15. Language Usage – Spelling (LU – S)

All the words of the Language Usage – Spelling were selected from the original list of Gates' (1937) Spelling Difficulties in 3,876 Words. The words were further selected on the basis of their prominence in everyday vocabularly. The incorrect spellings included in this test are those which proved to be the most frequent errors by Gates (1937). The correctly spelled words were selected on the basis of the findings of a subsequent study (Wesman, 1946). The final test consists of 100 right and wrong words. The following are the first six items of the Language Usage – Spelling test.

1. apointed
2. commission
3. limited
4. arival
5. comunity
6. variety

The subject is asked to indicate whether the spelling of a particular word is wrong or right on the answer sheet.

Test 16. Language Usage – Grammar (LU – G)

The Grammar part of the Language Usage test of the DAT consists of 40 sentences, each divided into five parts. For example:

where/did you/stop at/on your trip/to Chicago
A B C D E

The subject is asked to read the whole sentence and mark against the parts he considers wrong with respect to spelling, punctuation, and grammar.

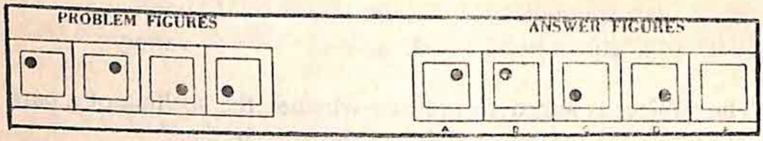
Test 17. Numerical Ability (NA)

The Numerical Ability scale of the DAT is designed to evaluate a subject's understanding of numerical relationships, his facility in handling numerical concepts, and his ability to deal abstractly with quantitative materials. This test consists of 40 problems of addition, subtraction, multiplication, division, square root, cube root, and the like followed by five answers for each. The subject indicates his response in the answer sheet by blackening the space under the alternative he feels is correct.

Test 18. Abstract Reasoning (AR)

The Abstract Reasoning test of the DAT is designed as a non-verbal measure of reasoning ability. Each item of this test requires the subject to perceive an operating principle in changing diagram presented in a series and give evidence of such understanding by designating an answer diagram from among the six which should logically follow the fourth problem figure. Diagram 2 is an example of the kind of items used in this test.

DIAGRAM 2



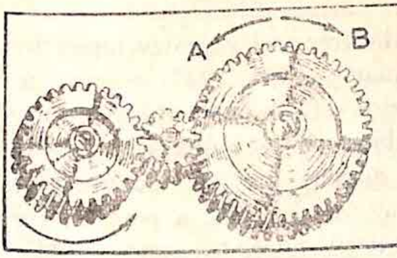
According to Bennett *et al.* (1966), the Abstract Reasoning test involves the ability to perceive relationships in abstract figure patterns, generalization, and self-education of principles from non-language designs.

Test 19. Mechanical Reasoning (MR)

The Mechanical Reasoning test of the DAT is essentially a new form of Bennett's Mechanical Comprehension Test. Each of the 68 items of this test consists of a pictorially presented mechanical situation with a simple worded question. Diagram 3 is an example of the type of items included in the Mechanical Reasoning test.

The latest edition of the DAT manual (Bennett *et al.*, 1966) provides split-half reliability coefficients for all the tests except Clerical Speed and Accuracy for which a parallel-form reliability coefficient was obtained. All these reliability coefficients

DIAGRAM 3



16

When the small gear on the left turns in the direction shown, which way will the big gear "X" turn ? (If it is not possible to know, mark C.)

were found to be reasonably high ranging from .80s for Clerical Speed and Accuracy and Language Usage – Grammar to, 90s for Space Relations and Verbal Reasoning.

The amount of validity data available on the DAT is considerable (Harris & Dole, 1956; Halsey, 1956; Doppelt, Seashore & Odgers, 1959; Stoughton, 1955). Most of these data are concerned with the predictive validity in terms of high school and college achievements. The fourth edition of the DAT manual summarizes a huge number of validity studies (Bennett *et al.*, 1966 : ch. 5).

It has been pointed out earlier that the DAT scales were selected for the present study primarily for their similarity with the WAIS. For example, Information, Comprehension, Similarities of the WAIS seem to be similar to Verbal Reasoning, Language Usage – Spelling, and Language Usage – Grammar of the DAT. Also Block Design, Picture Arrangement, and Object Assembly of the WAIS seem to be related to Spatial Relations and Mechanical Reasoning scales of the DAT. Finally, Digit Span and Arithmetic seem to have some degree of resemblance with Numerical Ability and Clerical Speed and Accuracy of the DAT.

It is also important to note that the nature of some of the DAT scales could be related to frequently identified factors of the WAIS. For example, Verbal Reasoning of the DAT seems to reflect a process similar to that of a Verbal Comprehension factor of the WAIS. Mechanical Reasoning and Spatial Relations seem to measure a process similar to that of a Perceptual Organization factor of the WAIS. A Freedom from Distractibility process which has been repeatedly found in WAIS (Cohen, 1952a, 1952b; Hover, 1950) seems indicative in the Language Usage – Spelling scale of the DAT.

Test 20. Advanced Progressive Matrices (PM – A)

The Advanced Progressive Matrices test was developed by Raven (1947) to measure Spearman's (1904, 1927) general intelligence or 'g'. The task consists of designs which require completion. In these tests the subject chooses one from among many designs that best fits the missing part of the question figure. An answer which fits may (a) complete a pattern, (b) complete an analogy, (c) systematically alter, (d) systematically resolve figures into parts. There are two sets of matrices in this test. The items of the first set are designed to introduce a person to the general nature of problems of the second test. The subject's total score in this test is his number of correct responses in the second set.

The manual for the Advanced Progressive Matrices (Raven, 1947) reports reliability coefficients which range from .76 to .90. But it does not contain any reports on validity. However, reviewing more than 70 validity studies Burke (1958) has concluded that the Progressive Matrices test is heavily loaded with a factor common to most intelligence tests (i.e., Spearman's 'g').

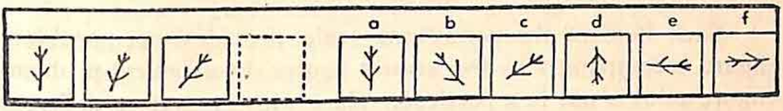
Culture Fair Intelligence Tests (CFIT) Scale III

The Scale III of the Culture Fair Intelligence Test (Cattell & Cattell, 1959) is essentially a paper-and-pencil test. Two major claims made for these scales are that they have high saturation on general ability and that they are relatively independent of school achievements, social advantages, and various forms of environmental influences (Horn & Cattell, 1966). This test consists of four subscales viz., Series, Classification, Matrices, and Conditions.

Test 21. Series (Ser)

The Series of the CFIT battery requires the subject to complete a sequence of four drawings by choosing one from among the six alternatives that are presented in the answer figures. Diagram 4 is an example of the items included in this scale.

DIAGRAM 4

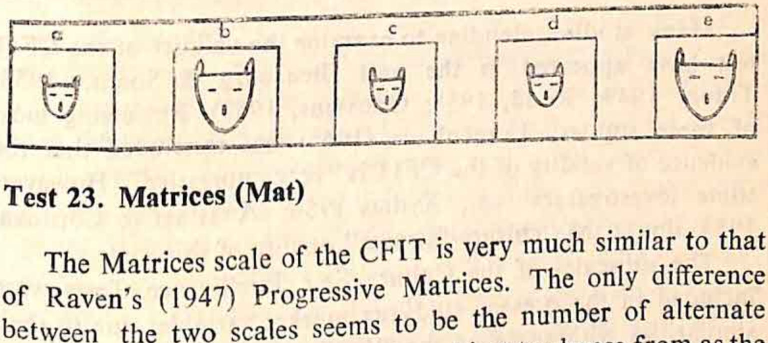


The Series consists of 13 items all of which bear similar principles involved in the Abstract Reasoning test of the DAT.

Test 22. Classification (Cl)

The Classification test of the Culture Fair battery requires the subject to pick out a pair from among the five drawings that are different from the other three similar ones. This test consists of 14 items and is administered for four minutes. Diagram 5 is the first item included in the Classification test.

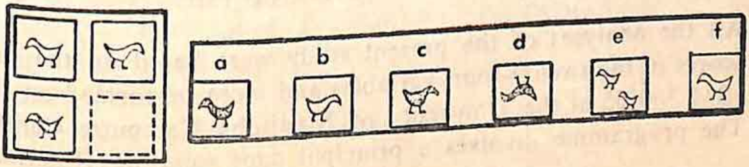
DIAGRAM 5



Test 23. Matrices (Mat)

The Matrices scale of the CFIT is very much similar to that of Raven's (1947) Progressive Matrices. The only difference between the two scales seems to be the number of alternate answers which are provided to the subject to choose from as the missing part of the main figures. Each of the problems of the Matrices scale consists of six alternate answers compared to eight in the Advanced Progressive Matrices test. This test consists of 13 items and is administered for three minutes. Diagram 6 is an example of items included in this scale.

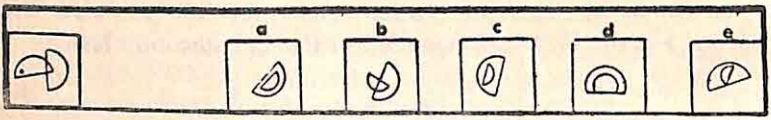
DIAGRAM 6



Test 24. Conditions (Cond)

Each item of the conditions scale provides one problem figure accompanied by five answer figures. In a typical problem figure a dot is put in a particular place with respect to different geometrical figures and the subject is asked to find a figure from among the five given alternatives where he could possibly put a dot without altering the principles involved in the placement of the dot. This test consists of ten items and is administered for two and a half minutes. Diagram 7 is the first item included in this test.

DIAGRAM 7



Many studies intending to examine the validity of the CFIT test have appeared in the past (Bensburg & Soaln, 1955; Tilton, 1949; Rodd, 1958; Goossens, 1952). Reviewing most of these studies, Tannenbaus (1965) has concluded that the evidence of validity of the CFIT is "very impressive". However, some investigators (i.e., Xydias 1956; Anastasi & Cordova, 1953) doubt the "culture-fairness" quality of this scale.

The subscales of the Culture Fair Intelligence Tests were included in the present study as marker variables due to their similarities with some of the WAIS performance scales. For example, Picture Completion, Block Design, Picture Arrangement, and Object Assembly seem to represent some degree of culture fairness because they have been repeatedly found measuring a Perceptual Organizatlon factor which is relatively independent of cultural influences (Cohen, 1952b; Berger *et al.*, 1964; Radcliffe, 1966).

THE PRELIMINARY ANALYSES

All the analyses of the present study were based on the raw scores of the twenty-four variables and were performed on the IBM 360/65 at the University of Manitoba Computre Centre. The programme involves a principal axes solution (Hotelling,

1933) with ones as the diagonal elements. It further rotates the principal axes solution to an unique Varimax analytic solution (Kaiser, 1958).

Two separate analyses were performed for the 18-19 and 25-34 age groups. This resulted in 24 principal component factors with a list of corresponding eigen values for both the groups which appear in Appendix F. Then the nature of major principal component factors of both the groups were grossly examined. It could be recalled that the basic objective of the present study was to compare the factor loading patterns of WAIS subscales across the 18-19 and 25-34 age groups. Such comparisons would require equal number of similar factors for both the groups. It was, therefore, necessary to examine the eigen values and select one from each of the groups that would result not only in equal number of similar principal component factors but also meet closely the criteria of "positive generalizability" (Kaiser and Caffrey, 1965) and the "scree test" (Cattell, 1966). According to Kaiser and Caffrey an eigen value of 1.00 is arbitrarily considered a point corresponding to the criterion of positive generalizability. On the other hand, the scree test involves plotting all the eigen values against the factors and finding a point where the curve approaches a straight line which could be used as a cutting point to retain factors. Retaining factors beyond this point is considered unnecessary because when the curve begins to approach a straight line it would simply indicate correlations among specific orthogonals in the population and error of measurement; both of which are unimportant for the purpose of the interpretation of factors.

Once the desired factors are rotated and interpreted, the most similar pairs of factors would be matched across the groups of the present study. Then Horn's (1961) corrected version of pattern correlation coefficient (r_p) would be used to determine psychometric invariance of the WAIS. Pattern correlation coefficient was considered to be the most appropriate because of its special implications (i.e., significant positive, insignificant, and significant negative) in the context of psychometric invariance assessment. These implications would be more fully described in the next chapter.

CHAPTER III

Results

The means and standard deviations for each variable were computed separately for the 18-19 and 25-34 age groups. Individual t-tests (Garrett, 1966 : 215) were then performed to find out if the two groups differed significantly with respect to their mean raw scores on different tests. These critical ratios and their significance levels appear in Appendix G.

An examination of the t-test results indicated that the 25-34 age group scored significantly higher ($P < .01$) on Comprehension, Vocabulary, and Spelling section of the Language Usage scales. These results are in agreement with those of many studies which have noted that the scores on Comprehension and Vocabulary scales continue to rise until the middle age (Garfield & Bleck, 1952; Trembly, 1964; Wechsler, 1958 : 203-204). The individual t-tests also indicated that the subjects of the 18-19 age group scored significantly higher ($P < .01$) on Numerical Ability, Arithmetic, Reasoning, Classification, and Matrices scales. These results are consonant with the findings which have demonstrated superior performance of younger groups on reasoning and performance tests (Riegel, 1959; Wechsler, 1958).

It is, however, interesting to note that both the age groups of the present study were matched overall with respect to their IQs on the WAIS. Table 3 indicates that the mean IQs of the 18-19 and 25-34 age groups were 111 and 112, respectively. Further, both the groups had the same Verbal IQ (viz., 114) and differed only by a negligible margin in Performance IQ. Also the differences in Verbal, Performance, and Full scale IQs between male and female subjects within each age group were negligible (see Table 3).

1. THE CORRELATIONS

As indicated earlier, most of the marker variables of the

TABLE 3 : **IQs for 18-19 and 25-34 Age Groups and Male and Female Subjects Within Each Age Group**

IQ	M	F	Pooled	M	F	Pooled	Difference within		Pooled
	18-19			25-34			18-19	25-34	
Verbal IQ	116	115	114	115	115	114	1	0	0
Performance IQ	107	106	106	108	110	108	1	2	2
Full Scale IQ	113	112	111	113	113	112	1	0	1

present study were chosen on the basis of their similarities with different subscales of the WAIS. The assumption of these markers being similar would be meaningful and valid if they correlate positively with different WAIS. Therefore citations of correlation coefficients of these markers with the WAIS were considered informative in that these correlations might further justify the inclusion of the markers in the present investigation. Since correlations serve as the basis for a factor analytic solution, the differences in correlation coefficients across the 18-19 and 25-34 age groups might be helpful in accounting for possible differences in the factor structures between these groups. For the purpose of clarity and parsimony only relevant portions of the correlation matrices of 18-19 (see Appendix H) and 25-34 (see Appendix I) age groups were included in the present section (see Table 4).

In the 18-19 age group Verbal Reasoning scale was found to be significantly correlated ($P < .05$) only with the verbal scales of the WAIS. But in the 25-34 age group this scale correlated significantly with almost all the WAIS. A similar trend was also indicated for the Grammar section of the Language Usage scale. In the 18-19 age group this test correlated significantly ($P < .05$ or .01) only with the Information, Comprehension, Similarities, and Vocabulary scales. But in the 25-34 age group the same test correlated significantly with all the WAIS. Arithmetic Reasoning correlated significantly with a few WAIS (i.e., Arithmetic, Block Design, and Object Assembly) in the 18-19 age group and with all the WAIS in the 25-34 age group. Also Advanced Progressive Matrices, Classification, Matrices, and Series correlated significantly ($P < .05$ or .01) with a few WAIS in the 18-19 age group but with all the performance scales and most of the verbal scales in the 25-34 age group. All these

TABLE 4 : Correlations of Marker Variables with WAIS Subscales

WAIS Subscale	VR		SR		CSA		LU – S		LU – G	
	18-19	25-34	18-19	25-34	18-19	25-34	18-19	25-34	18-19	25-34
Inf	.065	.411**	.245*	.105	–.031	.148	.343**	.080	.397**	.316**
Comp	.369**	.235*	.314**	.081	.072	.117	.069	.278**	.316**	.288**
Arith	.413**	.273**	.329**	.361*	–.069	.073	.179	.193	.170	.146
Sim	.245*	.417**	.274**	.218*	–.004	.123	.169	.204	.332**	.441**
D Sp	.036	.237*	.122	.196	–.005	.078	–.056	.194	–.004	.113
Voc	.653**	.550**	.258*	–.150	–.099	.080	.331**	.282**	.548**	.414**
D Sy	.177	.168	–.143	.180	.314**	.523**	.364**	.186	.190	.188
PC	.191	.418**	.179	.491**	.043	.239*	–.056	.104	.134	.221*
BD	.193	.451**	.411**	.537**	–.085	.096	–.045	–.004	.103	.322**
PA	.161	.394**	.185	.490**	.129	.047	.030	.166	.062	.321**
OA	.144	.383**	.417**	.481**	–.075	.022	–.054	.023	.114	.231*

(Contd.)

TABLE 4 (*Contd.*)

WAIS Subscale	NA 18-19	NA 25-34	AR 18-19	AR 25-34	MR 18-19	MR 25-34	PM – A 18-19	PM – A 25-34
Inf	.196	.284**	.128	.334**	.174	.189	.189	.187
Comp	−.044	.231*	.067	.232*	.231*	.032	.147	.142
Arith	.361**	.230*	.301**	.400**	.388**	.369**	.287**	.335**
Sim	−.036	.287**	−.084	.311**	.106	.044	.231*	.337**
D Sp	−.094	.025	.084	.219*	.067	.066	.149	.201
Voc	.041	.201	.189	.293**	.191	.322**	.209*	.261*
D Sy	.123	.131	.070	.263*	−.240*	−.033	−.021	.302**
PC	−.119	.257*	.098	.434**	.222*	.444**	.170	.490**
BD	.224*	.280**	.352**	.402**	.505**	.413**	.339**	.417**
PA	.081	.189	.120	.372**	.193	.340**	.060	.349**
OA	.121	.163	.245*	.440**	.346**	.253*	.298**	.481**

(*Contd.*)

TABLE 4 (*Contd.*)

WAIS	Ser		Cl		Mat		Cond	
Subscale	18-19	25-34	18-19	25-34	18-19	25-34	18-19	25-34
Inf	.121	.030	.224*	.146	.216*	.070	.326**	.101
Comp	.053	.031	.047	.024	.093	.180	.216*	.220*
Arith	.217*	.186	.221*	.345**	.176	.447**	.310**	.223*
Sim	.003	.132	.143	.171	.149	.334**	.198	.122
D Sp	−.121	.269*	.057	.155	.120	.177	.165	.154
Voc	.105	.130	.056	.193	.223*	.271**	.238*	.134
D Sy	−.032	.240*	.051	.209*	−.051	.279	−.085	.193
PC	.011	.363**	.062	.406**	.141	.374**	.055	.488**
BD	.196	.331**	.223*	.432**	.281**	.429**	.283**	.414**
PA	.154	.221*	.175	.321**	.056	.323**	.083	.344**
OA	.173	.424**	.303**	.389**	.212*	.343**	.198	.366**

Note : With N = 100 a correlation of .205 is significantly different from zero at the .05 level, and of .267 is similarly significant at the .01 level (see Garrett, 1966 : 201).

*P < .05

**P < .01

findings suggest that while most of the marker variables were appropriate markers of the WAIS in both the groups they were perhaps more general as marker in the 25-34 age group. The generality of the markers with the WAIS which was found in the present study is consistent with some other results. For example, Welford (1958) has pointed out that the normal elderly have a remarkable capacity for organizing their behaviour strategically in the face of problem situations. Such a capacity often affects scores in many different tests in a similar way and contribute to the greater number of correlations among various ability tests. This in effect suggests wider sources of variability of the WAIS for an older group which was evident in the present study.

Space Relations of the DAT were found to be significantly correlated ($P < .05$ or .01) with Arithmetic, Similarities, Block Design, and Object Assembly in both the groups. However, in addition to these common correlations, this scale was significantly correlated with Information, Comprehension, and Vocabulary scales in the 18-19 age group but with Picture Completion and Picture Arrangement scales in the 25-34 age group. Conditions were found to be similarly inconsistent in terms of its significant relationships with the WAIS subscales. For example, this marker was significantly correlated ($P < .05$ or .01) with Comprehension, Arithmetic, and Block Design in both the groups. However, in addition to these common correlations, conditions were found to be correlated with Information in the 18-19 age group but with Picture completion, Picture Arrangement, and Object Assembly in the 25-34 age group. These findings indicate that different sources of variability account for the performance on the same WAIS in the two age groups. Only then would the same markers correlate with different WAIS in the two age groups.

2. FACTOR SOLUTIONS

Based on the considerations outlined in the preceding chapter, a balanced decision was reached while attempting to choose cutting points to retain the factors for both the groups. Finally, eigen values of 1.02 and 0.95 were selected for the factor analysis of 18-19 and 25-34 age groups, respectively. These two cutting points were most acceptable under the present conditions because they were in the neighbourhood of 1.00 (criterion of positive generalizability), met the criterion of the scree test (see Figure 1), and resulted in an equal number of similar principal component factors in both the groups; the last being an unique requirement in the present investigation.

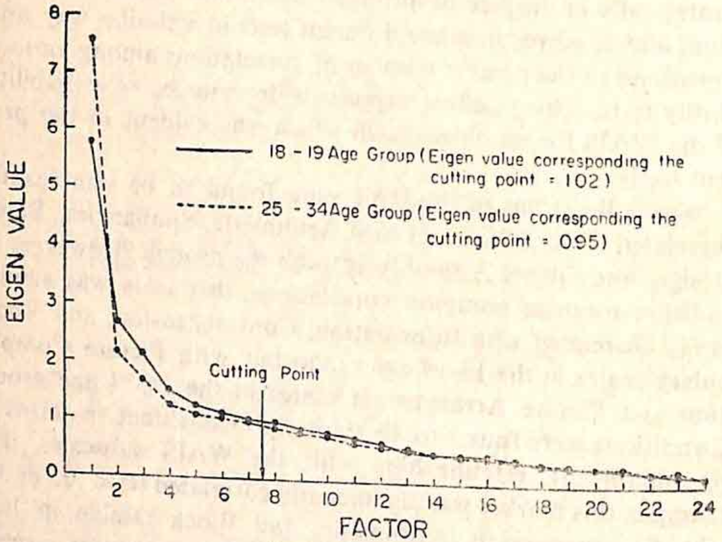


Figure I. Scree Test

The principal axis solutions (see Appendix J & Appendix K) were further rotated in accordance with the Varimax criterion (Kaiser, 1958) which approximates Thurstone's (1947) requirements of "simple structure" and "positive manifold". The Varimax rotation was chosen over the other techniques because of the orthogonality (independence) among resulting factors which is needed for matching the factors of the present study. These Varimax rotated solutions appear in Table 5 and Table 6 for 18-19 and 25-34 age groups, respectively.

3. COMMUNALITIES

It should be recalled that one of the objectives of the present study was to manipulate a condition that would lead to greater

TABLE 5 : **Varimax Factors for 18-19 Age Group**

Variable Number	Variable	Factor I	II	III	IV	V	VI	VII
1	Inf	023	−630	−065	−321	−008	318	118
2	Comp	101	−790	077	−026	128	−015	−098
3	Arith	285	−164	171	−740	043	118	093
4	Sim	−002	−692	005	160	002	−027	324
5	D Sp	−033	003	872	−205	013	−061	114
6	Voc	124	−757	050	−172	−112	−376	−152
7	D Sy	−058	−053	−572	169	383	447	−107
8	PC	165	−123	799	176	180	077	−073
9	BD	625	−094	−272	−321	060	−242	150
10	PA	185	−083	230	−252	559	−076	008
11	OA	607	060	078	318	−078	−124	332
12	VR	336	−476	078	−162	080	588	082
13	SR	706	−332	103	−056	091	−047	187
14	CSA	−134	027	−052	090	818	093	077
15	LU - S	−036	−121	−084	−089	039	813	090
16	LU - G	260	−485	040	077	−110	595	114
17	NA	262	180	−182	−446	127	406	377
18	AR	691	100	051	−211	053	337	−019
19	MR	762	−209	112	−227	015	−177	−058
20	PM - A	579	−135	130	016	031	181	356
21	Ser	494	049	−080	−095	−059	183	053
22	Cl	267	−005	055	−059	104	210	765
23	Mat	504	−107	128	−019	−216	188	107
24	Cond	178	−352	047	−338	−106	−101	506

Note : Decimal points omitted.

proportion of accountable variance of the WAIS. For this reason the present study factor analysed the WAIS along with several marker variables. It was proposed that an assessment of psychometric invariance of the WAIS would be more meaningful if it is based on a greater proportion of accountable variance (communality estimates or h^2) of the WAIS. Further, as expressed in eq. 4, under a most ideal situation, the proportion of h^2s of a scale should be the same as or at least be close to its reliability estimates (r_{jj}). It would be therefore important to examine the extent to which such requirements were met by the present study. The comparisons between the WAIS reliability estimates and the corresponding community estimates appear in Table 7.

TABLE 6 : Varimax Factors for 25-34 Age Group

Variable Number	Variable	Factor I	II	III	IV	V	VI	VII
1	Inf	074	133	021	156	−117	−027	846
2	Comp	068	646	086	174	−261	−048	100
3	Arith	246	005	063	356	058	729	066
4	Sim	075	582	041	331	141	−290	246
5	D Sp	089	075	048	079	837	068	−018
6	Voc	209	376	−045	119	092	165	−154
7	D Sy	212	099	753	157	091	165	−154
8	PC	702	037	176	139	−062	229	392
9	BD	730	120	056	198	−069	172	100
10	PA	587	148	−064	−021	086	321	318
11	OA	697	−011	179	090	164	−111	289
12	VR	316	309	004	488	255	043	429
13	SR	704	124	−084	269	176	133	002
14	CSA	070	040	862	091	−018	−046	150
15	LU – S	−132	666	236	−173	239	443	090
16	LU – G	260	722	−039	131	150	071	158
17	NA	046	188	082	732	−165	076	148
18	AR	329	100	123	648	174	059	233
19	MR	427	−061	−396	464	−055	285	152
20	PM – A	490	144	135	533	216	−033	093
21	Ser	553	−081	081	318	336	−241	−069
22	Cl	400	−130	131	375	182	227	155
23	Mat	369	162	080	668	093	160	−080
24	Cond	688	198	099	203	−106	−053	−152

Note : Decimal points omitted.

TABLE 7 : Reliability Estimates (r_{jj}) and Communalities (h^2) of the WAIS Subscales of Both the Groups

Estimate Source	r_{jj} Wechsler (1958)		h^2 Present Study		$r_{jj} - h^2$	
	18-19	25-34	18-19	25-34	18-19	25-34
Inf	.91	.91	.62	.79	.29	.12
Comp	.79	.77	.67	.54	.12	.23
Arith	.79	.81	.71	.73	.08	.08
Sim	.87	.85	.60	.62	.27	.23
D Sp	.71	.66	.82	.73	−.11	−.07
Voc	.94	.95	.79	.68	.15	.27
D Sy	.92	—	.72	.71	.20	—
PC	.82	.85	.76	.76	.06	.09
BD	.86	.83	.66	.64	.20	.19
PA	.66	.60	.48	.58	.18	.02
OA	.65	.68	.61	.65	.04	.07

Notes : 1. Reliability estimates were determined by split-half method and are based on the original standardization sample of the WAIS.
2. Plus and minus signs indicate that reliable variances were overdetermined and underdetermined, respectively.

It is apparent from Table 7 that most of the h^2s of WAIS in the present study were close to their reliability estimates. This was true in both the groups. So much so, that in a few cases (i.e., Digit Span in both the groups) the h^2s were actually higher than the reliabilities. Furthermore, if one is to accept an h^2 of .60 as an arbitrary minimum point to view a test variance as substantial, it could be seen that the present study was generally successful in its intent. All the h^2s except for Comprehension in 18-19 and Picture Arrangement in both the groups were found to be above this point. Speaking in relative terms, one of these three h^2s (i.e., for Picture Arrangement in 25-34 age group) was underdetermined only by 2% with respect to its reliability. However, it should be pointed out that the factor analysis of the present study used 1s as diagonal elements which might have inflated the components of the final factor matrices and subsequently the h^2s of different WAIS. Perhaps this was the reason why the h^2 of the Digit Span scale were overdetermined with respect to its reliability estimates.

4. INTERPRETATION OF FACTORS

Ordinarily, variables with factor loadings of .30 and above would be evaluated to identify the factors. But such a figure may not always prove to be scientifically noteworthy especially with respect to the interpretation of factor (Horn, 1965). Therefore, in the present study, it might be necessary to give greater weight to very high loading variables particularly for interpretations of ambiguous factors.

A supplementary criterion for interpreting factors of the present study would be to examine the nature of tests with near-zero loadings. This indirect approach for interpreting factors would be used only to resolve any confusion or difficulties arising from the results of the first approach.

(*a*) *18-19 Age Group*

Factor I

The variables with loadings above .30 on this factor are as follows:

19.	Mechanical Reasoning	+ .762
13.	Space Relations	+ .706
18.	Abstract Reasoning	+ .691
9.	Block Design	+ .625
11.	Object Assembly	+ .607
20.	Advanced Progressive Matrices	+ .579
23.	Matrices	+ .504
21.	Series	+ .494
12.	Verbal Reasoning	+ .336

This factor was interpreted as *spatial conceptualization.* The term "conceptualization" is used here to mean the ability to form a mental image as to how certain things might look if rotated or altered or moved according to a defined principle, given or implied. The interpretation of this factor is based on the process involved in the high loading variables such as Mechanical Reasoning, Space Relations, Abstract Reasoning, Block Design, etc. All these tests require the subject to conceptualize the answers in a spatial context using a reasoning process.

It is interesting to note that Block Design and Object Assembly of the WAIS have consistently been identified as measures of perceptual organization (Cohen, 1957; Berger *et al.*, 1964). In the present study, however, the first factor is represented by many other variables involving relations, reasoning, alterations in the context of space. Moreover, the interpretation of this factor as spatial conceptualization is consonant with the basic nature of a perceptual organization factor, because the former could be considered a part of the latter which is a much broader process.

The presence of Verbal Reasoning as a high loading variable need not be viewed as a deterrent to the interpretation of the first factor. First of all, the loading of this test is minimal compared to the other high loading variables. Second, Verbal Reasoning appears to have significant loading on the first factor not for its verbal components because all other variables with significant loadings on the second factor (i.e., verbal relations) have near-zero loadings on this factor. Rather it seems that the reasoning part of the Verbal Reasoning test contributed to its presence in the first factor. This rationale is further supported by the fact that most of the variables with high loadings on the first factor (i.e., Mechanical Reasoning, Advanced Progressive Matrices, Series, etc.) appear to have similar reasoning components.

Factor II

The variables with loadings above .30 on this factor are:

2.	Comprehension	−.790
6.	Vocabulary	−.757
4.	Similarities	−.692
1.	Information	−.630
16.	Language Usage – Grammar	−.485
12.	Verbal Reasoning	−.476
34.	Conditions	−.352
13.	Space Relations	−.332

This factor was identified as *verbal relations.* The first four high loading variables of this factor are all WAIS Verbal Scales (i.e., Comprehension, Vocabulary, Similarities, and Information). The other high loading variables are Language Usage – Grammar, Verbal Reasoning, Conditions, and Space Relations which suggest the presence of a verbal component manifested in relational terms. The loading of two non-verbal variables (i.e., Conditions and Space Relations) are not sufficiently high to suggest this factor to be of a non-verbal nature. Rather the presence of these variables in the second factor could be attributed to their reasoning components which are evident in all other high loading variables.

The verbal relations factor seems very similar to a verbal comprehension factor found in many previous studies on the WAIS alone (e.g., Cohen, 1957; Berger *et al.*, 1964). The present study, however, included many marker variables which might have expanded the limited nature of the verbal comprehension factor to broader process of verbal relations which is indicative in some of the WAIS and marker variables.

Factor III

Three variables load significantly on this factor. These are as follows:

5.	Digit Span	+ .872
8.	Picture Completion	+ .799
7.	Digit Symbol	− .572

The third factor of the 18-19 age group was identified as a *freedom from distractibility* factor. While interpreting this factor the sign of the high loading variables were noted since they are not the same. The variables with high positive loadings on this factor are Digit Span and Picture Completion which indicates the presence of a memory or carefulness process. However, a high negative loading of Digit Symbol which needs attention suggests this factor to be more of a process of freedom from distractibility than just a process of memory. The interpretation of this factor does not depart from the interpretation of similar process in other studies (i.e., Cohen, 1957; Berger *et al.*, 1964). In fact Cohen (1952a, 1952b) has interpreted a freedom from distractibility factor in a factor analysis of the W-B I scales.

Factor IV

Six variables have loadings above .30 on Factor IV. These are:

3.	Arithmetic	− .740
17.	Numerical Ability	− .446
24.	Conditions	− .338
1.	Information	− .321
9.	Block Design	− .321
11.	Object Assembly	+ .318

The fourth factor of the 18-19 age group was identified as *numerical manipulations*. The variables with loadings higher than .40 are Arithmetic and Numerical ability both of which suggest a process of manipulation of numbers. The other high loading variables on this factor (i.e., Conditions, Information, and Block Design), though requiring the ability to manipulate, do not manifest any numerical involvement. The Object Assembly which represents an opposite process by its differential sign than the rest of the high loading variables was of some help in resolving the ambiguity of this factor. In other words, if this factor really represents a process of numerical manipulation, the Object Assembly should prove itself to be non-numerical as well as non-manipulative in nature. This assumption is qualified by the fact that the Object Assembly scale has a high loading on a spatial conceptualization factor (i.e., Factor I) which is non-numerical as well as non-manipulative.

Factor V

The high loading variables on this factor are the following:

14.	Clerical Speed & Accuracy	+ .818
10.	Picture Arrangement	+ .559
7.	Digit Symbol	+ .383

The fifth factor of the 18-19 age group was identified as *perceptual speed.* Three tests which have significant high loadings on this factor are Clerical Speed and Accuracy, Digit Symbol, and Picture Arrangement. An examination of the nature of Clerical Speed and Accuracy and Digit Symbol scales indicates that higher scores on these variables are dependent on one's ability to perceive simple visual symbols and give proof of such perceptions through certain responses as quickly as possible.

The Picture Arrangement, though manifest speed component, does not seem to measure a simple perceptual factor. For an average subject this scale is supposed to measure a relatively higher perceptual task. However, considering the sample of the present study which was constituted of university students, it seems likely that the items of the Picture Arrangement scale were easier and therefore the scores seem to have depended solely on the speed of performance.

Factor VI

The high loading variables on this factor are the following:

15.	Language Usage – Spelling	+ .831
16.	Language Usage – Grammar	+ .595
12.	Verbal Reasoning	+ .588
7.	Digit Symbol	+ .447
17.	Numerical Ability	+ .406
6.	Vocabulary	+ .376
18.	Abstract Reasoning	+ .337
1.	Information	+ .318

The sixth factor of the 18-19 age group was identified as a *language usage* factor. There are eight variables which have loadings greater than .30. These are Language Usage – Spelling, Language Usage – Grammar, Verbal Reasoning, Digit Symbol, Numerical Ability, Vocabulary, Abstract Reasoning, and Information. Of these, both the Spelling and the Grammar parts of the Language Usage scale contributed more than half of the total variance of this factor. The use of language (in this case English) is also indicative in Verbal Reasoning, Vocabulary, and Information scales. But Digit Symbol, Numerical Ability, and Abstract Reasoning are primarily non-language tests. However, an evaluation of the nature of these tests indicates that they often require the subject to make use of "covert" language (i.e., counting in one's mind).

Factor VII

Six variables have high loadings on Factor VII:

22.	Classification	+ .765
24.	Conditions	+ .506
17.	Numerical Ability	+ .377
20.	Advanced Progressive Matrices	+ .356
11.	Object Assembly	+ .332
4.	Similarities	+ .324

The last factor of the 18-19 age group was interpreted as *analogy*. The nature of this factor seems straight forward. All the high loading variables of this factor (i.e., Classification, Conditions, Numerical Ability, Advanced Progressive Matrices, Object Assembly, and Similarities) manifest the process of analogy directly or indirectly.

(*b*) *25-34 Age Group*

Factor I

The relevant high loading variables on Factor I are:

9.	Block Design	+ .730
13.	Space Relations	+ .704
8.	Picture Completion	+ .702
11.	Object Assembly	+ .697
24.	Conditions	+ .688
10.	Picture Arrangement	+ .587
21.	Series	+ .553
20.	Advanced Progressive Matrices	+ .490
19.	Mechanical Reasoning	+ .427
22.	Classification	+ .400
23.	Matrices	+ .369
18.	Abstract Reasoning	+ .329
12.	Verbal Reasoning	+ .316

The first factor of the 25-34 age group was identified as *spatial conceptualization*. This factor seems to have a striking similarity with the first factor in the 18-19 age group. All the nine high loading variables of Factor I of the 18-19 age group are present in this factor. In addition to those nine, four other variables (i.e., Picture Completion, Conditions, Picture Arrangement, and Classification) load significantly on this factor. They all seem to represent a process of space conceptualization in terms of reasoning, logical thinking, or deduction.

It could be observed that more than half of the total variables of the present study load highly on this first factor which might erroneously suggest a process vaguely similar to a so-called 'g' factor. However, a closer examination indicates that all these high loading variables are performance or non-verbal variables. This is contrary to the nature of a general factor in which both non-verbal and verbal variables are supposed to load significantly. But most of the verbal variables of the present study load significantly on a language usage or verbal facility factor (i.e., Factors II & VII) of the 25-34 age group. The greater number of high loading variables on this first factor is evident because most of the marker variables of the present study turned out to be performance – or spatial-related variables (see Table 4).

Factor II

The variables with loadings more than .30 on the second factor of the 25-34 age group are:

16.	Language Usage – Grammar	+ .722
15.	Language Usage – Spelling	+ .666
2.	Comprehension	+ .646
4.	Similarities	+ .582
6.	Vocabulary	+ .376
12.	Verbal Reasoning	+ .309

This factor was interpreted as *language usage* factor. The high loading variables on this factor are Language Usage – Grammar, Language Usage – Spelling, Comprehension, Similarities, Vocabulary, and Verbal Reasoning. It seems that a subject's success on all these tests depends on his ability in making use of language (in this case the English language) in terms of spelling, grammar, punctuation, and reasoning. This factor is very similar to the sixth factor of the 18-19 age group.

Factor III

Variables with relevant factor loadings on Factor III are the following:

14.	Clerical Speed and Accuracy	+ .862
7.	Digit Symbol	+ .753
19.	Mechanical Reasoning	– .396

This factor was identified as *perceptual speed*. The variables with positive high loadings on this factor are Clerical Speed and Accuracy and Digit Symbol both of which involve simple perceptual tasks. For example, Clerical Speed and Accuracy requires the subject to identify a given symbol (e.g., 2b) from among other symbols. The Digit Symbol scale also requires the subject to associate certain symbols (e.g., =) with certain numbers (e.g., 9). In both the cases a subject is given sufficient practice trials which further simplify the tasks. The other important element which is common to both Clerical Speed and Accuracy and Digit Symbol is the element of time limit. Both these tests are given for certain amount of time during which no subject could possibly attempt all the items of the tests. In that sense both the Clerical Speed and Accuracy and Digit Symbol tests are basically speed tests. A subject's total score on these tests would therefore depend on the speed with which he responds or performs these simple perceptual tasks. The interpretation of this factor as perceptual speed is further qualified by significant negative loading of the Mechanical Reasoning scale which is essentially a power test.

Factor IV

Ten variables have factor loadings greater than .30 on Factor IV. They are:

17.	Numerical Ability	+ .732
23.	Matrices	+ .668
18.	Abstract Reasoning	+ .648
20.	Advanced Progressive Matrices	+ .533
12.	Verbal Reasoning	+ .488
19.	Mechanical Reasoning	+ .464
22.	Classification	+ .375
3.	Arithmetic	+ .356
4.	Similarities	+ .331
21.	Series	+ .318

The fourth factor of the 25-34 age group was interpreted as a *logical thinking* factor. At the surface, the nature of this factor seems close to the first factor of the 25-34 age group. Of the ten high loading variables of this factor, seven have been found to have high loadings on the first factor of this group. Such a situation is rather difficult to interpret. Therefore it was necessary to find out the variables which load highly on this factor but not on the first factor. These variables are Numerical Ability, Arithmetic, and Similarities all of which require the subject to think logically to get the right answers. The process of logical or deductive thinking is also evident in Matrices, Abstract Reasoning, Advanced Progressive Matrices, Verbal Reasoning, Mechanical Reasoning, Classification, and Series scales. This factor seems to be most similar to an analogy factor in the 18-19 age group.

Factor V

Two variables have relevant loadings on Factor V. These are:

5.	Digit Span	+ .837
21.	Series	+ .336

Digit Span which is supposed to measure a memory factor (see Cohen, 1957; Berger *et al.*, 1964) loads very highly on this factor. The other high loading variable on this factor is Series. Therefore this factor was conveniently identified as a *memory* factor. It is likely that for the 25-34 age group, Series bears some component of memory. This factor seems closest to the freedom from distractibility factor found in the 18-19 age group.

Factor VI

The high loading variables on the sixth factor are:

3.	Arithmetic	+ .729
15.	Language Usage – Spelling	+ .443
10.	Picture Arrangement	+ .321

This factor was identified as a *numerical speed* factor. Though speed is reflected in all the high loading variables, Arithmetic was the only test which manifests a numerical facility process. Further, the Numerical Ability test which should load highly on a numerical factor had actually a near-zero loading on this factor. Such a situation was difficult to explain properly. Therefore the interpretation of this factor was more guided (rather forced) by the highest loading variable (i.e., Arithmetic) which alone contributed more than two-thirds to its total variance. This factor seems to be most similar to the fourth factor of the 18-19 age group.

Factor VII

The following four variables have significant factor loadings on Factor VII.

1.	Information	+ .846
6.	Vocabulary	+ .667
12.	Verbal Reasoning	+ .429
8.	Picture Completion	+ .392

The last factor of the 25-34 age group was interpreted as a *verbal facility* factor. The high loading variables of this factor are Information, Vocabulary, Verbal Reasoning, and Picture Completion. All these tests seem to represent a common process which could be labelled as facility in verbal task. It is interesting to note that most of these high loading variables are present in the second factor of the 18-19 age group which was interpreted as verbal relations.

5. FACTOR SIMILARITY ACROSS THE GROUPS

It could be observed from the preceding section that no two factors of the 18-19 and 25-34 age groups were fully identical though spatial conceptualization, perceptual speed, and language usage were found in both. After a close study of the nature of the factors it was, however, possible to determine the most similar or approximately similar factors across the age groups. A table indicating factor similarities was then prepared to serve as reference for rearrangement of factor loadings which was essential for subsequent invariance analysis (see Table 8).

6. INVARIANCE ANALYSES

Horn's (1961) corrected version of the pattern correlation coefficient (r_p) was used to determine the similarities and differences between the psychometric patterns of WAIS across the age groups. The basic assumption of this analysis is that the dimensions (in the present context, the factors) be independent and

TABLE 8 : **Similar Pairs of Factors Across the 18-19 and 25-34 Age Groups**

Factor Order	Age group 18-19	Age group 25-34
I	(I) Spatial Conceptualization	(I) Spatial Conceptualization
II	(II) Verbal Relations	(VII) Verbal Facility
III	(III) Freedom from Distractibility	(V) Memory
IV	(IV) Numerical Manipulations	(VI) Numerical Speed
V	(V) Perceptual Speed	(III) Perceptual Speed
VI	(VI) Language Usage	(II) Language Usage
VII	(VII) Analogy	(IV) LogicalThinking

Note : The number in parentheses indicates the order of that factor in the rotated Matrices of Table 5 and Table 6. For the purpose of subsequent analysis these orders were rearranged to be consistent with the orders of the first column.

scores of the profiles or patterns have equal weights. The first assumption is implicit in orthogonal factors of the present study. The second assumption was approximated by converting all the raw scores (in this case, factor loadings) to standard scores.

Horn's r_p formula is based on Cattell's (1949) pattern correlation and Rao's (1948) difference squared (D^2). It presents an entirely new approach to pattern analysis. It is supposed to indicate the degree of similarily or dissimilarity between any two patterns with respect to their shapes, levels, and accentuations (steepness) all of which are worth exploring in the present study. The value of r_p varies from $+1.00$ through 0.00 to -1.00 indicating complete similarity (invariance), no relationship (lack of invariance), and complete dissimilarity (lack of invariance as well as complete difference) between any two patterns. An unique advantage of the corrected r_p over many existing pattern analyses is that its significance levels could be determined from a table provided by Horn (1961). The results of such invariance analyses for all the WAIS appear in the last column of Table 9.

The r_p values for Arithmetic, Digit Span, Vocabulary, and Block Design were all positive and significant at the .01 level. The r_p for Information was positive and significant at the .05 level. No test was found to have a significant negative r_p which would have implied a complete difference between factor loading patterns of a certain scale across the groups. Thus the r_ps of Comprehension, Similarities, Digit Symbol, Picture Completion, and Picture Arrangement were found to be insignificant in either direction (positive or negative). This suggested that though the above scales were psychometrically non-invariant, none of them was found to be completely different. A complete difference between any two patterns would have been indicated if the r_ps were negative and significant at a certain acceptable level (see Horn, 1961). The significance levels of negative r_ps could also be determined from Horn's table.

The factor loadings were also plotted to observe the stability of psychometric components of the WAIS across the age groups. Thus, for each scale two separate curves representing 18-19 and 25-34 age groups were also plotted with factor loadings on Y axis and similar factors on X axis (see Figures 2, 3, and 4). As expected from the r_p values, the curves for Information, Arithmetic, Digit Span, Vocabulary, and Block Design were very similar with respect to shapes, levels, and steepness. For the rest of the WAIS the curves for 18-19 and 25-34 age groups were not very similar.

It is perhaps important to discuss further the implications of all three possible outcomes of pattern analysis (i.e., significant positive, insignificant, and significant negative r_p values). In the present context when an r_p value between two factor loading patterns of a scale is found to be positively significant it would indicate a case of psychometric invariance of that scale. If such an r_p value is insignificant it would, however, suggest a case of lack of psychometric invariance of that scale. But if an r_p value is negative and significant it would represent a case of psychometric non-invariance as well as *psychometric difference* meaning thereby a certain test measures distinctly different things (factors) across the age groups. This distinction between lack of psychometric invariance (indicated by all the r_ps except positively significant ones) and psychometric difference (indicated by significant negative r_p) is particularly important to appreciate fully the implications of the present results. Therefore, it would seem that the lack of psychometric invariance is inherent in a case of psychometric difference of a scale but the reverse is not true.

TABLE 9 : **Pattern Correlation Coefficients (r_p) of Psychometric Components of WAIS Subscales Between Age Groups**

Variable	Age	Factor							r_p
	18-19	I	II	III	IV	V	VI	VII	
	25-34	I	VII	V	VI	III	II	IV	
Inf	18-19	023	−630	−065	−321	−008	318	118	.65*
	25-34	074	846	−117	−027	021	133	156	
Comp	18-19	101	−790	077	−026	128	−015	−098	−.17
	25-34	068	100	−261	−048	086	646	174	
Arith	18-19	285	−164	171	−740	043	118	093	.77**
	25-34	246	066	058	729	063	005	356	
Sim	18-19	−002	−692	005	160	−002	−027	324	.02
	25-34	075	246	141	−290	041	582	331	
D Sp	18-19	−033	003	872	−205	013	−061	114	.96**
	25-34	089	−018	837	068	048	075	079	
Voc	18-19	124	−757	050	−172	−112	376	−152	.92**
	25-34	209	667	092	164	−045	376	119	
D Sy	18-19	−058	−053	−572	169	383	447	−107	.01
	25-34	212	−154	091	165	753	099	157	

PC	18-19	165	−123	799	176	180	077	−073	−.17
	25-34	702	392	−062	229	176	037	139	
BD	18-19	625	−094	−272	−321	060	−242	150	.69**+
	25-34	730	100	−069	172	056	120	198	
PA	18-19	185	−083	230	−252	559	−076	008	−.09
	25-34	587	318	086	321	−064	148	021	
OA	18-19	607	060	078	318	078	−124	332	.46
	25-34	697	298	164	−111	179	−011	090	

Notes : 1. Decimal points omitted.

2. The order of factors of the 25-34 age group is consistent with that of Table 7.

3. Factor loadings were first converted to standard scores for which r_ps were computed.

* $P < .05$.

** $P < .01$.

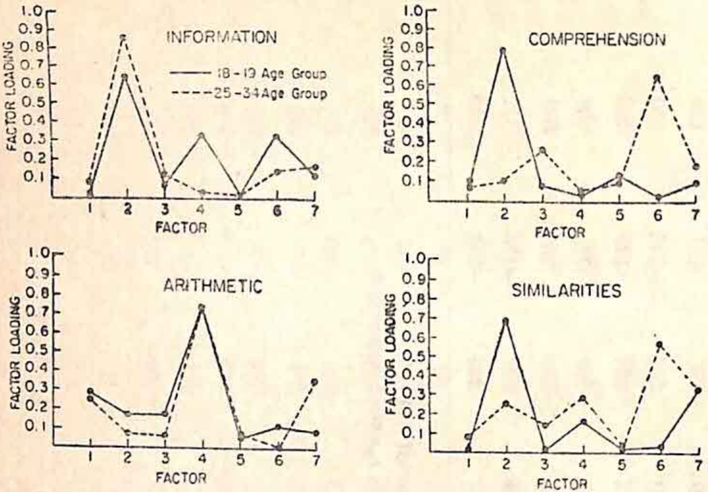


Figure 2. Factor Loadings of WAIS Subscales on Similar Factors for 18-19 and 25-34 Age Groups

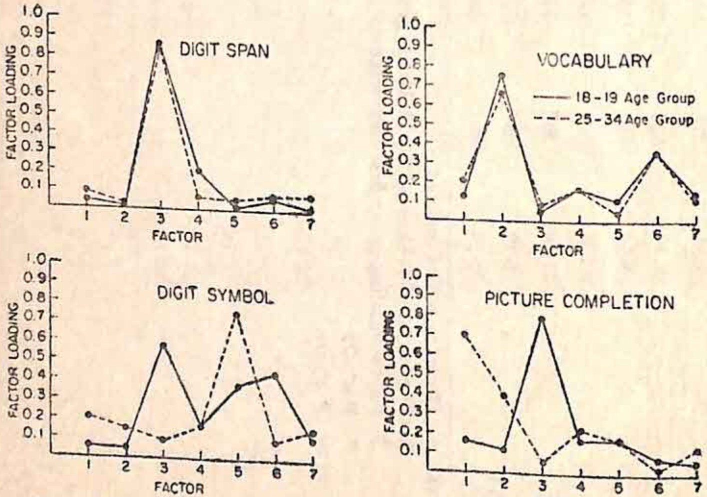


Figure 3. Factor Loadings of WAIS Subscales on Similar Factors for 18-19 and 25-34 Age Groups

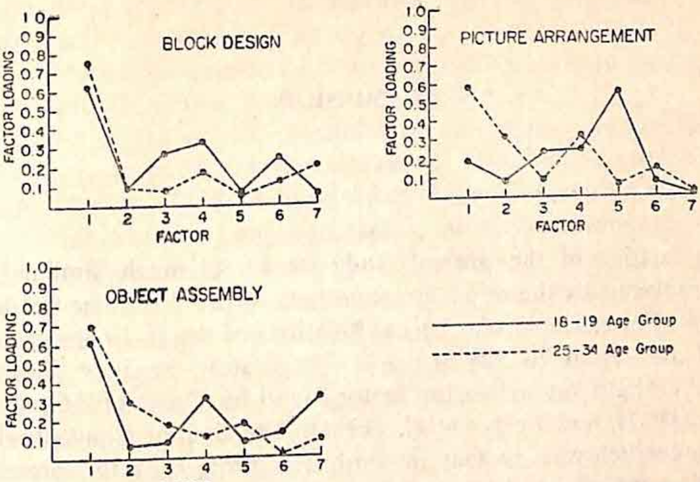


Figure 4. Factor Loadings of WAIS Subscales on Similar Factors for 18-19 and 25-34 Age Groups

CHAPTER IV

Discussion

The factors of the present study were very much similar to those found by the other investigations of the WAIS or similar tests. For example, the Verbal Relations of the 18-19 age group and the Verbal Facility of the 25-34 age group are very similar to a Verbal Comprehension factor found by Davis (1956), Cohen (1957), and Berger *et al.* (1964). The Spatial Conceptualization which was evident in both the groups of the present study seems to be similar to Staley's (1973) Spatial Visualization and Horn and Cattell's (1966) "fluid" factor. Also the Freedom from Distractibility factor of the 18-19 age group and the Memory factor of the 25-34 age group have been found in almost all the studies on W-B I and WAIS (Berger *et al.*, 1964; Cohen, 1952a, 1952b; Green & Berkowitz, 1964; Riegel & Riegel, 1962). The Perceptual Speed factor which was evident in both the groups has been identified by Davis (1956) under a different name (i.e., General Speediness). Davis has also found a Numerical Speed Facility factor which was found in the 18-19 (Numerical Manipulations) and 25-34 (Numerical Speed) age groups of the present study. The Analogy factor of the 18-19 age group and Logical Thinking of the 25-34 age group have also been identified by Staley and Davis under different names (i.e., Ability to Perceive Relationships, Logical Reasoning, and General Reasoning).

The Language Usage factor which was evident in both the groups of the present study has not been proposed by any of the factor analytic investigations of WAIS subscales. The emergence of Language Usage factor was perhaps due to the inclusion of Spelling and Grammar parts of the Language Usage and Verbal Reasoning scale in the present study all of which were the principal contributors to the variance of this factor in both the groups.

The present study included a number of marker variables to raise the magnitude of accounted variance (h^2) of the WAIS through the emergence of strong or overdetermined factors. It is therefore important to find out whether or not these markers were actually similar in relation to the WAIS.

Most of the marker variables of the present study did in fact prove to be appropriate markers in that they all correlated with different WAIS. Among them Verbal Reasoning, Grammar section of the Language Usage, Abstract Reasoning, Advanced Progressive Matrices, Classification, Matrices, and Series were perhaps the most appropriate markers because they correlated with most of the WAIS subscales in both the groups. Clerical Speed and Accuracy was the only scale which was found to be relatively less general as a marker of the WAIS because it correlated significantly only with the Digit Symbol scale in both the groups. Space Relations and Conditions were found to be somewhat inconsistent as markers in that they had very few common significant correlations and more unique significant correlations across the groups. As indicated earlier, this was perhaps due to different sources of variability of WAIS across the age groups. Only then could the same markers correlate differently with the WAIS across the age groups.

The principal purpose of the present investigation was to assess the stability of psychometric compositions of the WAIS subscales across certain specified groups under the conditions of maximum possible accounted variance (h^2) for these scales. Perhaps an examination of the obtained h^2s would indicate the extent to which the present study was successful in achieving this prerequisite for the subsequent invariance analyses.

Considering a value of .60 as arbitrarily significant it could be observed that 19 out of the 22 (11 WAIS × 2 groups) h^2s of the present study were beyond this point leaving behind only three which were in the neighbourhood of .50. This indicates that greater percentages of the total variance of any tests are accounted for if these tests are factor analysed with appropriate marker variables. The generality of this finding with respect to the h^2s of the WAIS has also been supported by Staley (1973). Based on the Varimax solutions of Staley's 18-19 age group it was found that the h^2s of the Digit Span, Arithmetic, and Similarities were all above .60. Block Design was the only scale in Staley's study that missed this arbitrary point by a small margin.

Perhaps reliability estimates (r_{tt}) are the toughest criteria against which the obtained h^2s could be tested to determine the extent to which the present study was successful in accounting for reliable variance of the WAIS. It could be observed from Table 7 that such a comparison was even more encouraging. For most of the WAIS the difference between the present h^2s and the corresponding reliability estimates were small. Interestingly, one of the three scales with less than .60h^2 in absolute sense (i.e., Picture Arrangement in the 25-34 age group) did in fact differ from its reliability estimate only by a margin of .02. This would mean that the present study was successful in accounting for all the variance of the Picture Arrangement scale except for 2%.

A relative comparison of h^2s and corresponding reliability estimates further indicated that the present study was more successful in accounting for the variance of most of the performance scales than the verbal scales. Such a condition seems to be related to the choice of the marker variables most of which (approximately two-thirds) proved to be performance-related scales (see Table 4). The greater proportion of performance-related markers may have resulted in the emergence of a strong Spatial Conceptualization factor in both the groups. On the other hand, verbal-related markers were comparatively fewer in the present study which was less likely to lead to a similar strong or overdetermined verbal factor.

The h^2s of the WAIS in the present study overwhelmingly support the hypothesis of Cattell (1952) and the implications of Davis' (1956) results. Accordingly, the inclusion of marker variables in a factor analysis of certain tests should help to determine greater accountable variance (h^2) of those tests; a condition considered as a necessary prerequisite for the assessment of psychometric invariance (Aftanas, 1971a). On the basis of the obtained results it could be concluded that such a condition was generally achieved in the present study.

In the present study two important indices were evaluated to determine the stability of psychometric components of the WAIS. One of these was a visual examination of each scale's psychometric components across the age groups. The other was a statistical inference based on the pattern correlation coefficient (r_p) between a scale's factor loading patterns across the two age groups.

Based on the above considerations, the Information scale was found to be psychometrically invariant across the present age groups. The contribution to the h^2s of this scale mainly came from Verbal Relations (i.e., 40%) and Verbal Facility (i.e., 64%) factors in the 18-19 and 25-34 age groups, respectively. These two factors were considered to be the most similar pair of factors found in the two groups. A more detailed examination indicated that in the 18-19 age group the Information scale received approximately 20% of its total variance from Numerical Manipulations and Language Usage factors which were unique to this group. However, this different sources of variability of the Information scale was rejected by the statistical criterion. The r_p between the psychometric components of this test across the age groups was found to be positive and significant at the .05 level. It suggested that the Information scale is psychometrically invariant, at least across the age groups of the present study. Such a finding should, however, be viewed with respect to the fact that 29% and 12% of the reliable variance was unaccounted for in the 18-19 and 25-34 age groups, respectively.

One interesting thing with regard to the present findings is that these results were in close agreement with those found by the previous investigators. For example, in Cohen's (1957) study Information was found to have significant loadings on a Verbal Ccomprehension factor across the 18-19 and 25-34 age groups. The results obtained by Berger *et al.* (1964) study are also in agreement with those of the present study. In their study Information was found to load significantly on a Verbal Comprehension factor in both 18-19 and 25-34 age groups.

The Arithmetic scale was also found to be psychometrically stable across the age groups of the present study. Visual examination of the psychometric components indicated that two similar factors (i.e., Numerical Manipulations and Numerical Speed in the 18-19 and 25-34 age groups, respectively) contributed more than 50% to the total variance of the Arithmetic scale. The only difference in these two psychometric patterns was that a Logical Thinking factor contributed 12% to this scale's variance only in the 25-34 age group. The observed psychometric stability of Arithmetic scale was further supported by the corresponding r_p which was positive and significant at the .01 level. The present results with regard to the Arithmetic scale are supported by Staley (1973) in the context of different age groups (i.e., 18-19 and 20-24).

It could be recalled that contrary to the present results, Aftanas (1971b) observed lack of stability of psychometric components of the Arithmetic scale across the age groups which he inferred from the Berger *et al.* (1964) data. There seems to be several reasons for this difference. First of all, Aftanas interpreted the results of Berger *et al.* (1964) which used the highest correlations of the column/row as the community estimates as opposed to 1s in the present study. Also the results of the Berger *et al.* (1964) study are based on WAIS subscales whereas the results of the present study are based on a host of marker variables in addition to the WAIS subscales. Finally, the previous interpretations were directed towards four age groups (i.e., 18-19, 25-34, 45-54, and 60-75+ in Berger *et al.*) whereas the implications of the present results are restricted only to the 18-19 and 25-34 age groups. In that sense, perhaps Aftanas is right in suspecting the psychometric invariance of the Arithmetic scale in the context of the entire adult span. The present results, however, do not support or reject the contentions with regard to the stability of psychometric components of the Arithmetic scale.

The pattern correlation coefficient for the Digit Span was among the highest (i.e., .95) and was significant at the .01 level. Examination of the psychometric components of the Digit Span across the groups further indicated this test's high degree of psychometric stability because each of the similar pair of factors (i.e., Freedom from Distractibility and Memory) contributed more than 69% to its accounted variance. The present findings were also supported by Cohen's (1957) study in which the contributions of a Memory factor to the variance of the Digit Span scale were approximately the same across the 18-19 and 25-34 age groups.

The obtained results with regard to the stability of psychometric contents of the Digit Span scale seem to contradict those found by Berger *et al.* (1964). In their study the variance of the

Digit Span scale was accounted for by a Verbal factor in the 18-19 age group and a Memory factor in the 25-34 age group. Berger *et al.* interpreted their findings in terms of Memory "coalescing" with Verbal factor in the former age group. On the contrary, the inclusion of several marker variables in the present study perhaps resulted in "splitting" (a process opposite to coalescing) of factors to more primary ones. Therefore the age-related differences in psychometric patterns of the Digit Span in the Berger *et al.* (1964) study might have been an artefact resulting from its methodological limitations.

Vocabulary was another among the WAIS which was found to be psychometrically invariant. In the 18-19 age group Verbal Relations and Language Usage contributed 55% and 13% respectively to the variance of the Vocabulary scale. In the 25-34 age group Verbal Facility and Language Usage factors accounted for 45% and 13% respectively to its accounted variance. An examination of the graphs indicated that the patterns of psychometric components in both the groups were almost identical (see Figure 3 : Vocabulary). The pattern correlation coefficient between the psychometric components of the Vocabulary scale was found to be .92 which was significant at the .01 level (see Table 9). This, too, suggested a high degree of psychometric stability of the Vocabulary scale across the age groups of the present study.

The findings of the present study seem to be in agreement with those found by Cohen (1957) and Berger *et al.* (1964) who noted similar results for the Vocabulary scale across the same age groups. However, these findings could not be regarded as entirely conclusive. For this scale's variance was underdetermined by wide margins of 15% and 27% in the 18-19 and 25-34 age groups, respectively (see Table 7).

In the present study Block Design was also found to be psychometrically invariant. A Spatial Conceptualization factor contributed to this scale's variance by 38% and 53% in the 18-19 and 25-34 age groups, respectively. Unique to the 18-19 age group was a Numerical Manipulation factor that contributed approximately 10% to this scale's total variance. The invariance of psychometric components of the Block Design scale was also supported by a positive pattern correlation coefficient which was significant at the .01 level. It implies that Block

Design measured essentially the same factors for the two age groups; a finding consistent with that in the Berger *et al.* (1964) and Cohen (1957) studies.

The present results seem to contradict the observations of Staley (1973) who noted Block Design as a measure of Visualization in the 18-19 age group and Logical Reasoning in the 25-34 age group. However, the Spatial Conceptualization and Numerical Manipulation factors of the present study are very similar to the Visualization and Logical Reasoning factors of Staley's study. In that sense the only point of conflict seems to be a near-zero contribution of the Visualization factor to the variance of the Block Design scale in Staley's study contrary to a significant contribution of a similar factor (i.e., Spatial Conceptualization) in the second group. The reason for this conflicting results seems related to the age groups sampled in the concerned studies. For example, Staley's second group consisted of subjects between the ages of 20 and 24 where as the second group of the present study consisted of subjects between the ages of 25 and 34.

Sources contributing to the variance of the Comprehension scale across the groups were far from agreeing. In the 18-19 age group a Verbal Relations factor contributed 62% whereas in the 25-34 age group a Language Usage factor contributed a maximum of 41% to the accounted variance of this scale (see Table 9, and Figure 2 : Comprehension). This finding seems to confirm Matarazzo's (1972) reservations concerning the contents of the Comprehension scale. According to him, "precisely what intellectual processes the Comprehension scale involves is difficult to say". But the results of the present study with regard to the Comprehension scale seem to be in conflict with those of Berger *et al.* (1964) and Cohen (1957) in which a Verbal Comprehension factor contributed significantly to the variance of this scale equally across the same age groups.

A closer examination of the nature of the contributing factors indicates that overdependence on factor matching in the present study might have resulted in incompatible factor loading patterns on the Comprehension scale. For example, the Verbal Relations in the 18-19 age group and the Language Usage in the 25-34 age group which contributed uniquely to the variance of the Comprehension scale could hardly be treated as exclusive or dissimilar factors. Rather on a general level the Language Usage could be considered as a part of the Verbal Relations factor. However, these two factors were not matched with each other. The factor matchings of the present study were done with reference to the other factors in a search to find out the most similar pairs of factors. Considering such a global approach, the Verbal Relations Factor of the 18-19 age group was perhaps the most suitable match of the Verbal Facility factor of the 25-34 age group.

In addition to the disadvantages of factor matching there seems to be another difficulty which cautions against any straightforward conclusions with regard to the psychometric invariance of the Comprehension scale. It could be recalled that in the present study a substantial percentage of the reliable variance of the Comprehension scale was not accounted for, particularly in the 18-19 age group (see Table 7). Such a situation did not seem to create a comfortable base for any tangible conclusions concerning the stability of psychometric patterns of the Comprehension scale.

Similarities were found to be the only scale for which reliable variance was underdetermined by more than 20% in both the 18-19 and 25-34 age groups. Therefore, any observations concerning the psychometric invariance of this scale would be rather less conclusive. However, on the basis of whatever reliable variance was established it could be pointed out that the Similarities scale did not prove itself to be psychometrically invariant across the present age groups. This scale was found to have one pair of similar factors (i.e., Analogy and Logical Thinking in the 18-19 and 25-34 age groups, respectively) as a common source of variance each of which contributed approximately 10% to the total variance of the Similarities scale. In addition to this, Verbal Relations alone contributed 64% to this scale's total variance in the 18-19 age group. In the 25-34 age group approximately 34% of the reliable variance of the Similarities scale was contributed by a Language Usage factor. This trend was further supported by a near-zero pattern correlation coefficient between the psychometric components of this test across the groups.

The present results with regard to the psychometric invariance of the Similarities scale seem to be inconsistent with those found by Staley (1973). In his study only a Concrete Reasoning factor contributed (i.e., 16%) to the accounted variance of the Similarities scale in the 18-19 age group. On the other hand, in the 25-34 age group a Non-Quantitative factor contributed to this test's variance by more than 20%.

The results of the present study and the observations of Staley both seem to be in conflict with those found by Cohen (1957) and Berger *et al.* (1964) in which the psychometric invariance of the Similarities scale was suggested. These differences, however, could be attributed to the methods of analysis used in the concerned studies. For example, both Cohen and Berger *et al.* used Thurstone's (1938) oblique solutions for subsequent rotations. On the other hand, Staley and the present study used Hotelling's (1933) principal component solutions and Kaiser's (1958) Varimax rotations for the above purposes.

The results concerning the psychometric invariance of the Digit Symbol scale were rather confusing. In the 18-19 age group, too, many factors contributed to this scale's total variance as opposed to one significant contributing factor in the 25-34 age group. For example, in the first group Freedom from Distractibility, Perceptual Speed, and Language Usage contributed to Digit Symbol's variance by 32%, 14%, and 19%, respectively. But in the second group only a Perceptual Speed factor contributed 55% to the total variance of this scale (see Table 9). An examination of the graphs representing psychometric components of the Digit Symbol scale indicates dissimilarity between the groups (see Figure 3 : Digit Symbol). These findings contradict particularly those found by Cohen (1957) in which the Digit Symbol scale measured the same factor (i.e., a Digit Symbol factor) consistently across the same age groups. On the contrary, Berger *et al.* (1964) results were in agreement with those found in the present study.

The indication that the Digit Symbol in the 18-19 age group measures Freedom from Distractibility, Perceptual Speed, and Language Usage may be viewed differently. It is possible that the subjects of the younger group did not pay much attention while working on the Digit Symbol scale which is a minimum prerequisite of this scale. This might have been caused by the way subjects were briefed prior to the testing sessions. For example, all the subjects except for 10 volunteers in the 25-34 age group were told that they would not receive any feedback about their test results. Perhaps this denial of feedback created a general lack of seriousness or inattention particularly in the younger group. But there seem to be no studies suggesting age-different reactions to the denial of feedback. Therefore the obtained lack of psychometric invariance across the two age groups of the present study may well be intrinsic to the Digit Symbol scale.

The Picture Completion scale was found to lack psychometric invariance across the age groups of the present study. In the 18-19 age group Freedom from Distractibility was the only significant factor which contributed 62% to the total variance of this test. But in the 25-34 age group Spatial Conceptualization and Verbal Facility factors contributed significantly to this scale's variance. The r_p value between the psychometric components of this scale across the age groups was found to be non-significant (i.e., $-.17$). This finding could be viewed as more conclusive because the total accounted variance of Picture Completion scale was marginally underdetermined for both the groups (see Table 7).

The sources of variability of the Picture Completion scale in the 25-34 age group are generally consistent, particularly with Cohen's (1957) study in which this scale was found to measure a Picture Completion factor. But in the 18-19 age group this scale measured Freedom from Distractibility factor; a result unusual but not completely unexpected considering the general nature of the younger group. As pointed out earlier, perhaps for this group the accomplishment in the Picture Completion scale was mainly dependent on the subject's attention to the test materials. The nature of this scale supports this hypothesis because according to Matarazzo (1972) Picture Completion demands some amount of attention (Freedom from Distractibility) as a minimum prerequisite in order to notice the missing parts of different objects. The possible implication of general inattention in the younger group has already been discussed in another context.

The Picture Arrangement scale was found to lack psychometric invariance across the age groups of the present study. In the 18-19 age group a Spatial Conceptualization factor contributed 33% whereas in the 25-34 age group a Perceptual Speed factor contributed by to 30% the accounted variance of the Picture Arrangement scale. This was further confirmed by an insignificant pattern correlation coefficient between the factor loading patterns of the Picture Arrangement scale. The significant contributions of a Spatial Conceptualization factor seem to be in agreement with the other studies in which a Perceptual Organization factor contributed almost equally to the total variance of the Picture Arrangement scale across the 18-19 and the 25-34 age groups.

The indication that the Picture Arrangement scale measured a Perceptual Speed factor in the 18-19 age group need not be viewed as unexpected because the scoring of this scale was done not only on accuracy of performance but also the time required to complete the problems. Perhaps this speed aspect of the Picture Arrangement problem overshadowed its accuracy aspect in the younger group.

A Spatial Conceptualization factor contributed 36% and 47% respectively to the accounted variance of the Object Assembly scale in the 18-19 and 25-34 age groups. This was consistent with the findings of Berger *et al.* (1964) and Cohen (1957) who reported a similar factor (i.e., Perceptual Organization) contributing to the accounted variance of this scale. In addition to this common factor, Numerical Manipulations and Analogy each contributed approximately 10% to the variance of this scale in the 18-19 age group.

The lack of psychometric stability of the Object Assembly scale is perhaps due to various approaches which might be involved in solving the problems of this test. Wechsler (1958), for example, lists at least three possible ways a subject might approach the problems of this scale. These alternate approaches could be an immediate perception of the whole accompanied by a critical understanding of relations among the parts or a rapid recognition of the whole but imperfect understanding of the relations among the parts or a trial-and-error approach. It is therefore possible that subjects belonging to different age groups might act differently in their attempts to solve the problems of the Picture Arrangement scale.

The notion of fluid and crystallized intelligence and their developmental functions in particular seem to provide adequate explanations for the lack of psychometric stability of some of the WAIS subscales which were found in the present study. According to this theory all the primary abilities are organized into two principal dimensions such as fluid intelligence and crystallized intelligence (Cattell, 1957, 1963; Horn, 1965; Horn & Cattell, 1966). The fluid intelligence ('gf') is said to be a product of the influences of biological factors which starts declining in the mid-twenties. Crystallized intelligence ('gc') is believed to be a product of socio-cultural learning which grows until the late adulthood (Horn & Cattell, 1967).

Relating the psychometrically non-invariant scales of the present study with the other theoretical formulations it could be observed that the nature of the psychometrically non-invariant scales (i.e., Picture Completion, Picture Arrangement, and Object Assembly) seems similar to the measures of fluid intelligence because the performance on these tests is supposed to be independent of socio-cultural learning. Since fluid intelligence declines after the mid-twenties (Horn & Cattell, 1967), one would expect that the sources of variability of the above scale attributable to a fluid-type factor (i.e., Spatial Conceptualization) would be appreciably greater in the older group than in the younger group. An examination of the sources of variance of the Picture Completion Scale confirms this assumption. For example, the Spatial Conceptualization factor contributed more than 50% to the total variance of this scale in the 25-34 age group compared to only 15% in the 18-19 age group. Similarly, the Spatial Conceptualization factor contributed to the total variance of the Picture Arrangement scale by 33% in the 25-34 age group compared to only 3% in the 18-19 age group. This fact was also evident for the Object Assembly scale which was found to be psychometrically non-invariant in the present study. In the 25-34 age group the Spatial Conceptualization factor contributed 47% to this scale's total variance compared to 30% in the 18-19 age group (see Table 9).

The other group of non-invariant scales of the present study were Comprehension and Similarities both of which could be considered as measures of crystallized intelligence because the performance on these tests seems to be dependent on socio-cultural learning. Since crystallized intelligence keeps growing until late adulthood (Horn & Cattell, 1967), one would expect that a crystallized-type factor (i.e., Verbal or Language Usage) would contribute appreciably more to the variance of the Comprehension and Similarities scales. This hypothesis is also supported in the present study. It could be observed that in the 18-19 age group a Verbal Relations factor contributed 62% to the total variance of the Comprehension scale as opposed to only 1% in the 25-34 age group. Similarly, a verbal factor (Factor VII) contributed 47% to the variability of the Similarities scale in the 18-19 age group compared to only 5% in the 25-34 age group.

It was difficult to relate the psychometric non-invariance results of the Digit Symbol scale to any existing theory because there is hardly any agreement as to what this scale actually measures. For example, Cohen (1952a, 1952b) found that the variance of the Digit Symbol scale is associated with Freedom from Distractibility, Non-verbal Organization, Visual Organization, and Simple Speed factor for subjects of different ages.

It should be pointed out that although a cross-sectional approach is appropriate in determining psychometric invariance, it does not necessarily justify the interpretations of psychometric non-invariance. Therefore the psychometrically non-invariant scales of the present study may well be age (maturational)- and/or cohort (generational)- related. However, from the practical point of view, it is unimportant to separate the magnitude of these two effects because when a test is given to an 18-year-old or a 25-year-old at a point in time these maturational stages are invariably coupled with the same cohort.

The implications of assessment of psychometric invariance of tests in general and the results of the present study in particular are far more useful than would be expected from an assessment of reliability and validity. Such an idea has already been suggested by Aftanas (1971a) and subsequently elaborated by Puhan (1978c) through their references to the relationship between psychometric invariance and reliability and validity.[1] It would probably be helpful to understand the details of these relationships. Before this is done it is perhaps important to outline the meaning of these terms.

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[1] The term validity will be used hereinafter to mean factorial validity. Comparisons with other kinds of validity were considered unnecessary because they are not related to the concept of psychometric invariance.

Reliability refers to the consistency of test scores obtained by the same test when administered at different occasions or to different groups of individuals at the same point in time (Anastasi, 1968; Cattell, 1964; Gulliksen, 1950; Guttman, 1955). Validity refers to the extent a test measures what it intends to measure. According to this approach, the investigator attempts to determine the degree to which the factor loadings of a measure are identified with the constructs it intends to measure (Cronback & Meehl, 1955; Guilford, 1954; Gulliksen, 1950; Loevinger, 1957). On the other hand, the assessment of psychometric invariance consists of determining the "degree to which the sources of variability associated with a measure are invariant under conditions of change" (Aftanas, 1971a).

It could be further pointed out that psychometric invariance seems to emphasize two key points. First of all it is based on a multivariate approach to the variance of a test. Such an approach is considered more realistic (Thurstone, 1947) and has definite advantages over a single score approach (Guilford, 1948). Secondly, an assessment of psychometric invariance intends to evaluate the consistency or stability (invariance) of these multiple sources of variance of a test across some specified dimensions (i.e., groups, occasions, equivalent tests, etc.)

Relating reliability with the underlying requirements of the psychometric invariance assessment of a measure it would seem that a traditional reliability test examines only the consistency or stability of a single score across a specified dimension (i.e., groups, occasions, etc.) but lacks a multivariate approach to the test variance (see Table 10). Therefore, the concept of *psychometric reliability* is introduced here to mean what Aftanas referred to as an assessment of consistency of psychometric components (and not of a single score) of a test when administered across the groups (i.e., developmental or cultural), occasions (i.e., time periods), tests (i.e., equivalent or parallel forms), etc. This would represent Cattell's (1964) transferability or hardiness reliability to mean consistency across the groups in a multivariate context.

It is important to note that the results of the present study could be used as indices of psychometric reliability of different

TABLE 10 : Schematic Representation of the Relationship between Psychometric Invariance and Reliability and Validity

Traditional Test	Psychometric Invariance	
Requirements	Approach is Multivariate	Consistency is the Goal
Reliability	Lacks Multivariate approach to the test variance	Examines consistency of total score across occasions, equivalent forms, etc.
Validity	Based on multivariate approach to the test variance	Does not examine consistency across any dimension

scales across the age groups. For example, based on the present results it seems that the Information, Arithmetic, Digit Span, Vocabulary, and Block Design subscales are psychometrically reliable across the age groups because a consistency in the psychometric components of each of these scales was observed along the age dimension. Based on the present results one could also conclude that the Comprehension, Similarities, Digit Symbol, Picture Completion, Picture Arrangement, and Object Assembly subscales were psychometrically unreliable across the present age groups because they manifested the lack of psychometric consistency across the age dimension.

A traditional test of validity is based on a multivariate approach to a test variance but lacks the consistency or stability requirements of a psychometric invariance assessment (see Table 10). This is so because a traditional validity test is usually done on a single group of subjects at a single point in time. Therefore the concept of *psychometric validity* is introduced here to mean the extent to which the psychometric components of a test are identified with the constructs being measured (Aftanas, 1971a) and consistently so under conditions of change (i.e., across the groups, occasions, equivalent tests, etc.).

The results of the present study could also be used as indices to evaluate the psychometric validity of the WAIS subscales. For example, one could conclude that the Information, Arithmetic, Digit Span, Vocabulary, and Block Design subscales are psychometrically valid across the present age groups because a certain amount of stability in terms of what they are identified with is observed across the age dimension. It could also be pointed out that the Comprehension, Similarities, Digit Symbol, Picture Completion, Picture Arrangement, and Object Assembly subscales lack psychometric validity because they all suffered from the lack of stability across the age groups in terms of what they are identified with.

According to Puhan (1978c), the implications of psychometric invariance of a test are far more useful than those of traditional reliability and validity assessment. For instance, a psychometric invariance assessment across time would examine the stability of factor loading patterns of that test across two different occasions. This would represent a case of test-retest psychometric reliability. Such an invariance assessment, too, could be used to answer whether or not the major sources of variability of a test are consistently identified with the construct(s) being measured across time periods to represent a case of psychometric validity across time. Similarly, a psychometric invariance assessment across two parallel tests would not only represent parallel-form of psychometric reliability but also psychometric validity across equivalent tests. Puhan (1978c) further proposed for replacement of traditional reliability and validity assessments of a test by an appropriate kind of psychometric invariance assessment.

One of the difficulties with the psychometric invariance assessment perhaps relates to a fundamental level where the investigator might get trapped between two conflicting operations; the techniques of factor matching across any two or more groups and the possibility of psychometric non-invariance of any tests.

On the basis of other results (i.e., Cohen, 1957; Berger *et al.*, 1964) one cannot rule out the possibility of non-invariant psychometric components of a test across any two groups. In fact the results of the present study appear to confirm such a possibility. On the other hand, if the psychometric components of a test across the groups are different it is almost impossible to match the factors adequately which is a necessary prerequisite for any kind of invariance analysis. Perhaps an hypothetical example would be helpful to explain this point.

Let us assume that the Digit Span scale really represents an extreme case of psychometric non-invariance across two age groups (i.e., group A and group B). This could mean that the Digit Span would load significantly on a Memory factor in group A and an Analogy factor in group B. Let us further assume that the Similarities scale represents another extreme case of psychometric non-invariance across the same age groups. This could mean that the Similarities scale would load significantly on an Analogy factor in group A and a Memory factor in group B. In fact, both these assumptions are within the scope of psychometric invariance. They simply indicate what might possibly happen to the sources of variance of a test across the groups (see Table 11 : Before Matching).

TABLE 11 : **A Hypothetical Example of an Inherent Problem with the Assessment of Psychometric Invariance**

BEFORE MATCHING

Test	Group A Factor I Memory	Group A Factor II Analogy	Test	Group B Factor I Memory	Group B Factor II Analogy
1 Digit Span	*	—	1 Digit Span	—	*
2 Similarities	—	*	2 Similarities	*	—
			Interpretation :	Analogy	Memory

AFTER MATCHING

Test	Group A Factor I Memory	Group A Factor II Analogy	Test	Group B Factor I Memory	Group B Factor II Analogy
1 Digit Span	*	—	1 Digit Span	*	—
2 Similarities	—	*	2 Similarities	—	*

*Significant factor loading.

Now, since the interpretation of a factor is done in accordance with the high loading variables, it is more than likely that the investigator would interpret a Memory factor of group B as an Analogy factor because Similarities (the high loading test) is an analogy test. Following the same logic, the investigator would most likely interpret a real Analogy factor in group B as a Memory factor because its high loading variable is Digit Span which is supposedly a measure of Memory. There seems to be no way to determine that Digit Span really measures or loads on an Analogy factor in group B. Being unaware of this possibility, the investigator would then reorder or match factor II of group B with factor I of group A and factor I of group B with factor II of group A (see Table 11 : After Matching). He would thereby conclude erroneously that both Digit Span and Similarities are psychometrically invariant. In effect, a situation like this might misguide the investigator to cover up rather than discover the real differences in the psychometric patterns of a test between the groups.

It should be pointed out that the possibility of such a cover-up seems to have only limited significance to the results of the present study. This difficulty seems applicable only to the legitimacy of the matchings of Perceptual Speed and Freedom from Distractibility factor of the 18-19 age group and Perceptual Speed and Memory (doublet) factors of the 25-34 age group in the present study. This may explain, at least partially, the obtained lack of psychometric invariance of the Digit Symbol scale which loaded on the Perceptual Speed factors of both the groups. It might well be that the Digit Symbol scale measured a Perceptual Speed factor in the 18-19 age group and a Freedom from Distractibility factor in the 25-34 age group and Digit Span measured a Memory factor in the 18-19 age group and a Perceptual Speed in the 25-34 age group. However, as indicated earlier, it is difficult to counter this problem and even to know whether or not it existed in the present study. Perhaps future investigations could include many marker variables for the Digit Symbol and Digit Span scales and determine the Perceptual speed and Memory (Freedom from Distractibility) factors more adequately to avoid this situation.

Another factor matching problem that was experienced in the present study was how to match two sets of factors when they are in fact different across the groups. The magnitude of such a difficulty could be greatly reduced through trial-and-error attempts. For example, before any ultimate analyses were performed, the present study used a very small eigen value as the cutting point and factor analysed the scores on the 24 variables in both the groups. These preliminary analyses then retained the same number of principal component factors as the number of variables and indicated all the corresponding eigen values. Then the nature of the first fifteen principal component factors were grossly examined in both the groups. After an observation of the nature of these factors in both the groups two eigen values (i.e., 1.02 and 0.95) were used for the final analyses. Fortunately, in the present study these two eigen values not only approximated Kaiser and Caffrey's criterion of positive generalizability and Cattell's (1966) requirements of the scree test, but also retained an equal number of roughly similar factors for both the groups of the present study. In spite of all these considerations, the final analyses resulted in an Analogy factor in the 18-19 age group and a Logical Reasoning factor in the 25-34 age group which were rather unique to each of the groups. Therefore the psychometric invariance assessment of any test owing to the contributions of these two factors were not considered to be very conclusive. This was particularly true for the Similarities scale that loaded an Analogy factor in the 18-19 age group and a Logical Reasoning factor in the 25-34 age group.

The major limitations of the present study are associated with the sampling procedures. While educational levels and sex of the subjects in both within and across the age groups were carefully controlled, no adequate step was taken to control the socio-economic status of the samples. Besides, the subjects of the 18-19 age group were all full-time students whereas the subjects of 25-34 age group were mostly part-time students with various professional backgrounds (i.e., pilots, secretaries, sales persons, mechanics, school teachers, housewives, etc.). The heterogeneity of the subjects sampled obviously expands the scope of generalizability of the results. But at the same time it is likely that the present age groups were not adequately characterized which would have been possible had the above factors been more carefully controlled.

It has already been pointed out that in the present study the ratio of the WAIS performance scales to their markers was much higher (i.e., 5 : 9) compared to the WAIS verbal scales to their markers (i.e., 6 : 4). Such a situation seems to have helped the emergence of a strong performance factor (i.e., Spatial Conceptualization) in both the groups. On the other hand, there was not a single relatively strong verbal factor in either groups.

This was the main reason why no conclusive results were obtained with regard to the psychometric invariance of Comprehension and Similarities subscales. The future studies should, therefore, investigate more carefully sampled age groups and include a greater proportion of verbal markers to derive more conclusive results.

CHAPTER V

Summary

The purpose of the present study was to assess the psychometric invariance of the WAIS subscales across 18-19 and 25-34 age groups. Such an assessment required the examination of stability of factor loading contents of the WAIS subscales across various age groups.

A review of the related literature suggested that some of the WAIS subscales do not meet the requirements of psychometric stability particularly across the 18-19 and 25-34 age groups. However, these findings are based on the factor analyses of the WAIS subscales alone. Therefore several marker variables were proposed to be included in a factor analytic investigation of the WAIS for the 18-19 and 25-34 age groups. Psychometric stability of the WAIS across these two age groups was considered to be the minimum requirements of these scales being psychometrically invariant in the entire adult life-span context. Further, a cross-sectional strategy was considered to be the only appropriate one because the psychometric stability of the WAIS were to be examined across the two age groups at a point in time.

A total of 200 subjects (i.e., 100 in each age group) were tested in four testing sessions. In the first session all the subjects were tested individually by the WAIS. In the subsequent three sessions the subjects were given all the scales of DAT, CFIT, and PM-A in small groups.

Prior to any essential analyses the raw scores of all the 24 variables in both the groups were separately factor analysed using a very small cutting point (i.e., 0.01) to obtain principal component factors. This resulted in 24 principal component factors in each of the two groups. The nature of the first 15 factors of both the groups was then grossly examined. Finally, on the basis of the scree test results, criterion of positive generalizability, and the requirements of equal number of similar factors, two eigen values were selected to retain principal component factors for subsequent Varimax rotations. In the 18-19 age group the resulting rotated factors were interpreted as Spatial Conceptualization, Verbal Relations, Freedom from Distractibility, Numerical Manipulations, Perceptual Speed, Language Usage, and Analogy. In the 25-34 age group the seven rotated factors were interpreted as Spatial Conceptualization, Language Usage, Perceptual Speed, Logical Thinking, Memory, Numerical Speed, and Verbal Facility. The factors of both the groups were matched in pairs on the basis of their similarities. The revised version of Cattell's pattern correlations were then computed to determine the stability of psychometric components of all the WAIS subscales across the age groups.

The principal findings of the present study were as follows :

1. Considering reliability estimate (r_{jj}) as the maximum possible total common variance of a test, it was found that the total variance of the WAIS (as indexed by h^2s) were satisfactorily accounted for in the present study. Such a condition provided a much needed prerequisite for psychometric invariance assessments of the WAIS subscales. The general success in accounting the total variance of the WAIS was attributed to the inclusion of several marker variables in the present study.

2. Information, Arithmetic, Digit Span, Vocabulary, and Block Design scales were found to be psychometrically invariant across the present age groups. It was suggested that these scales should be further examined across other age groups in order to establish their psychometric stability across the entire adult life-span.

3. Comprehension, Similarities, Digit Symbol, Picture Completion, Picture Arrangement, and Object Assembly scales were found to be psychometrically non-invariant across the present groups. These findings were interpreted in terms of the developmental trends of fluid and crystallized intelligence. The implications of these results suggested that these subscales are psychometrically non-invariant or lack psychometric invariance across the entire adult life-span. However, owing to the limitations of factor matching procedures no definite conclusions were drawn with regard to these apparently psychometrically non-invariant scales.

4. The results of the invariance analyses indicated that none of the WAIS subscales was found to have significantly different (distinctly dissimilar) factor loading patterns across the age groups because no r_p value of the present study was found to be negatively significant at an acceptable level. This suggested that while certain WAIS were psychometrically invariant and certain others were psychometrically non-invariant, none of them proved to be psychometrically different across the age groups.

The implications of the present results were mainly related to the concepts of test reliability and validity. It was suggested that evaluation of psychometric invariance could simultaneously examine psychometric reliability and psychometric validity, both of which were proposed as more useful and realistic alternatives to the traditional reliability and validity assessments of a measure.

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APPENDICES

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APPENDIX A

Cross-Cultural Comparisons of the Factor Loading Patterns of WAIS and HOWIE subtests[1]

Variable	Sample	Factor			
		A	B	C	D
Inf	G-H[2]	.56	.04	.11	.44
	A-W[3]	.29	−.09	.41	.10
Comp	G-H	.57	−.05	.37	.20
	A-W	.39	.01	.38	−.10
D Sp	G-H	.14	.19	.32	.26
	A-W	.00	.09	.45	.03
Arith	G-H	.26	.24	.35	.23
	A-W	.04	.06	.35	.08
Sim	G-H	.73	.11	−.09	.38
	A-W	.42	.10	.10	.02
Voc	G-H	.21	.41	.07	.43
	A-W	−.06	.29	.21	.20
PA	G-H	.51	.44	−.22	.22
	A-W	.30	.20	−.09	.10
PC	G-H	.28	.23	−.05	.58
	A-W	.07	.04	.01	.38
BD	G-H	.26	.50	.07	.43
	A-W	.00	.58	.09	.00
OA	G-H	.08	.53	−.09	.34
	A-W	−.01	.56	−.03	.03

1. Riegel and Riegel (1962).
2. German sample tested by HAWIE.
3. American sample tested by WAIS.

APPENDIX B

Developmental Comparisons of the Factor Loading Patterns of the WAIS Information Subtest[1]

Age Group	Factor		
	Verbal Comprehension	Perceptual Organization	Memory
18-19	.30	.09	.04
25-34	.21	−.00	.10
45-54	.36	−.05	.10
60-70+	.29	−.09	.41

1. Cohen (1957).

APPENDIX C

Developmental Comparisons of the Factor Loading Patterns of the WAIS Digit Span Subtest[1]

Age Group	Factor		
	Verbal Comprehension	Perceptual Organization	Memory
18-19	.50	.05	−.01
25-34	.10	.03	.42
45-54	.08	.09	.44
60-70+	.38	.07	.09

1. Berger *et al.* (1964).

APPENDIX D

Comparison of the h^2s and the Reliability Estimates (r_{jj}) of WAIS Subscales

Variable	h^2			r_{jj}	
	WAIS (Cohen, 1957) 18-19 Age Group	WAIS (Berger *et al.*, 1964) 18-19 Age Group	W-B (Davis, 1956) 12-16 Age Group	W-B (Dermer Aborn & Canton, 1950) 18-19 Age Group	WAIS (Wechsler, 1958) 18-19 Age Group
Inf	.10	.35	.60	.86	.91
Comp	.12	.34	.39	.74	.79
Arith	.12	.29	.68	.62	.79
Sim	.06	.38	.48	.71	.87
D Sp	.09	.27	.33	.67	.71
Voc	.07	.47	.58	.88	.94
D Sy	.03	.30	.49	.80	.92
PC	.01	.37	.37	.83	.82
BD	.13	.37	.65	.84	.86
PA	.09	.26	.32	.64	.66
OA	.13	.38	.28	.69	.65

Note :—h^2s were calculated from existing studies.

APPENDIX E

Description of the Tests Used in the Present Study

Vari-able	Title of Variable	Title Abbre-viated	No. of Items in the Test	Nature of Testing	Time Limit	Scoring Procedure	Maximum Raw Score
1	Information	Inf	21	Ind[1]	NTL[2]	Number of Rights	21
2	Comprehension	Comp	14	Ind	NTL	All items scored two, one, or zero	28
3	Arithmetic	Arith	14	Ind	*Item Time* 1 & 2 15″ each 3-10 30″ each 11-14 60″ each	*Item Score* 1-10 1 or 2 11-14 2, 1, or 0	18
4	Similarities	Sim	13	Ind	NTL	All items scored two, one, or zero	26
5	Digit Span	D SP	—	Ind	NTL	Digit Forward + Digit Backward	17
6	Vocabulary	Voc	40	Ind	NTL	All items scored two, one, or zero	80
7	Digit Symbol	D Sy	90	Ind	Each item is presented for 20″ maximum	Number of Rights $+\frac{1}{2}$ the number of reverse responses.	90

(*Contd.*)

APPENDIX E (*Contd.*)

Vari-able	Title of Variable	Title Abbre-viated	No. of Items in the Test	Nature of Testing	Time Limit	Scoring Procedure	Maximum Raw Score
8	Picture Completion	PC	21	Ind	*Item* *Time* 1-6 60″ each 7-10 120″ each	Number of Rights	21
9	Block Design	BD	10	Ind	*Item* *Time* 1-6 60″ each 7 & 8 120″ each	*Item* *Score* 1, 2, 6 4, 2, or 0 3-5 4 or 0 7 & 8 6, 5, 4, or 0	48
10	Picture Arrangement	PA	8	Ind	*Item* *Time* 1-6 60″ each 7 & 8 120″ each	*Item* *Score* 1, 2, 6 4, 2, or 0 3-5 4 or 0 7 & 8 6, 5, 4, or 0	36
11	Object Assembly	OA	4	Ind	*Item* *Time* 1 & 2 60″ each 3 & 4 120″ each	*Item* *Score* 1 1-8 2 1-13 3 1-11 4 1-12	42
12	Verbal Reasoning	VR	50	G[3] - 15[4]	30' N	Number of Rights	50
13	Space Relations	SR	40	G - 15	25'	R-W	100

(*Contd.*)

APPENDIX E (*contd.*)

Vari-able	Title of Variable	Title Abbre-viated	No. of Items in the Test	Nature of Testing	Time Limit	Scoring Procedure	Maximum Raw Score
14	Clerical Speed and Accuracy Part 1 & 2	CSA	100	G - 15	3'	Number of Rights of Part two	100
15	Language Usage I : Spelling	LU – S	100	G - 15	10'	R-W	100
16	Language Usage II : Grammar	LU – G	50	G - 15	25'	W-R	95
17	Numerical Ability	NA	40	G - 15	30'	R-$\frac{1}{4}$ W	40
18	Abstract Reasoning	AR	50	G - 15	25'	R-$\frac{1}{4}$ W	50
19	Mechanical Reasoning	MR	68	G - 15	30'	R-$\frac{1}{4}$ W	68
20	Advanced Progressive Matrices	PM – A	36	G - 10	NTL	Number of Rights	36
21	Series	Ser	13	G - 10	3'	Number of Rights	13
22	Classification	Cl	14	G - 10	4'	Number of Right Pairs	14
23	Matrices	Mat	13	G - 10	3'	Number of Rights	13
24	Conditions	Cond	10	G - 10	150"	Number of Rights	10

1. Individual
2. No time limit
3. Group
4. Size of the group

APPENDIX F

Eigen Values Based on the Principal Component Solutions

Factor	Eigen Value	
	18-19 Age Group	25-34 Age Group
I	5.73	7.58
II	2.66	2.16
III	2.15	1.69
IV	1.48	1.24
V	1.24	1.19
VI	1.16	1.09
VII	1.05	0.97
VIII	1.00	0.88
IX	0.88	0.76
X	0.86	0.75
XI	0.77	0.64
XII	0.62	0.62
XIII	0.58	0.55
XIV	0.57	0.53
XV	0.52	0.49
XVI	0.50	0.48
XVII	0.42	0.42
XVIII	0.34	0.39
XIX	0.33	0.37
XX	0.32	0.31
XXI	0.29	0.29
XXII	0.20	0.23
XXIII	0.17	0.20
XXIV	0.14	0.14

APPENDIX G

Mean and Standard Deviations of Different Scales for the 18-19 and 25-34 Age Groups

Variable Number	Variable	18-19 (N = 100)		25-34 (N = 100)		t
		X	SD	X	SD	
1	Inf	20.59	3.59	22.05	3.26	3.01**
2	Comp	19.39	3.63	21.98	2.62	5.78**
3	Arith	13.39	2.48	13.80	2.64	0.55
4	Sim	19.20	3.38	19.18	2.90	0.05
5	D Sp	12.36	5.75	11.45	1.96	1.50
6	Voc	58.78	9.41	65.00	8.53	3.86**
7	D Sy	64.64	10.16	62.84	10.24	1.25
8	PC	14.66	4.83	15.06	3.04	0.71
9	BD	38.58	7.15	39.96	7.79	1.21
10	PA	24.27	5.31	25.47	5.76	1.54
11	OA	33.24	6.47	35.32	5.95	2.36*
12	VR	35.80	7.06	35.67	8.05	0.12
13	SR	52.30	20.67	50.69	22.28	0.53
14	CSA	66.53	13.90	65.58	13.27	0.49
15	LU – S	72.78	29.65	82.68	15.65	3.94**
16	LU – G	44.49	15.19	45.62	15.35	0.52
17	NA	32.14	6.26	28.27	9.16	3.49**
18	AR	40.19	5.08	37.00	8.76	3.16
19	MR	40.48	12.40	42.76	13.23	1.26
20	PM – A	23.70	5.33	23.61	4.94	0.12
21	Ser	8.07	1.42	7.92	4.94	0.73
22	Cl	7.15	2.22	6.36	2.21	2.52**
23	Mat	6.25	1.51	5.63	1.76	3.03**
24	Cond	5.78	1.52	5.45	1.37	1.61

Note : Statistics in the table are based on the raw scores.

* $P < .05$.

** $P < .01$.

APPENDIX H

Product-Moment Correlations of the Twenty-four Variables for the 18-19 Age Group

	1	2	3	4	5	6	7	8
1								
2	.446							
3	.295	.176						
4	.308	.395	.106					
5	−.041	.046	.286	.040				
6	.587	.580	.290	.388	.056			
7	.149	−.024	−.076	.008	−.500	.119		
8	.054	.172	.118	.085	.538	.111	−.219	
9	.074	.036	.370	.117	−.058	.096	.018	−.148
10	.124	.084	.187	.065	.199	.050	−.034	.208
11	−.093	.012	.059	.026	.052	−.088	−.041	.189
12	.065	.369	.413	.245	.036	.653	.177	.191
13	.245	.314	.329	.274	.122	.258	−.143	.179
14	−.031	.072	−.069	−.004	−.005	−.099	.314	.043
15	.343	.069	.179	.169	−.056	.331	.364	−.056
16	.397	.316	.170	.332	−.004	.548	.190	.134
17	.196	−.004	.361	−.036	−.094	.041	.123	−.119
18	.128	.067	.301	−.084	.084	.189	.070	.098
19	.174	.231	.388	.106	.067	.191	−.240	.222
20	.189	.147	.287	.231	.149	.209	−.021	.170
21	.121	.053	.217	.003	−.121	.105	−.032	.011
22	.224	.047	.221	.143	.057	.056	−.051	.062
23	.216	.093	.176	.149	.120	.223	−.051	.141
24	.326	.216	.310	.198	.165	.238	−.085	.055

	9	10	11	12	13	14	15	16
1								
2								
3								
4								
5								
6								
7								
8								
9								
10	.202							
11	.343	.142						
12	.193	.161	.144					
13	.411	.185	.417	.427				
14	−.085	.129	−.075	.044	−.023			

(Contd.)

APPENDIX H (*Contd.*)

	9	10	11	12	13	14	15	16
15	−.045	.030	−.054	.480	.011	.072		
16	.103	.062	.114	.694	.348	−.092	.476	
17	.224	.081	.121	.331	.220	.106	.310	.235
18	.352	.120	.245	.324	.500	.002	.242	.266
19	.505	.193	.346	.337	.572	−.090	−.103	.188
20	.339	.060	.298	.386	.503	.003	.112	.301
21	.196	.154	.173	.273	.333	−.084	.100	.124
22	.223	.175	.303	.332	.304	.086	.181	.217
23	.281	.056	.212	.263	.225	−.080	.119	.246
24	.283	.083	.198	.273	.345	−.073	.006	.249

	17	18	19	20	21	22	23	24
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18	.413							
19	.210	.437						
20	.288	.489	.418					
21	.213	.259	.231	.226				
22	.380	.231	.173	.423	.298			
23	.129	.382	.392	.279	.279	.258		
24	.202	.216	.263	.223	.054	.281	.250	

APPENDIX I

Product-Moment Correlations of the Twenty-four Variables for the 25-34 Age Group

	1	2	3	4	5	6	7	8
1								
2	.266							
3	.152	.153						
4	.246	.324	.032					
5	−.011	.027	.161	.101				
6	.513	.313	.266	.407	.115			
7	−.056	.053	.203	.107	.116	.080		
8	.348	.163	.423	.221	.082	.094	.250	
9	.175	.182	.334	.177	.096	.292	.289	.568
10	.322	.062	.331	.208	.128	.348	.123	.526
11	.256	.129	.220	.181	.180	.283	.161	.568
12	.411	.235	.273	.417	.237	.550	.168	.418
13	.105	.081	.361	.218	.196	.150	.180	.491
14	.148	.117	.073	.123	.078	.080	.523	.239
15	.080	.278	.193	.204	.194	.282	.186	.104
16	.316	.288	.146	.441	.113	.414	.188	.221
17	.284	.231	.230	.287	.025	.201	.131	.257
18	.334	.232	.400	.311	.219	.293	.263	.434
19	.189	.032	.369	.044	.066	.322	−.033	.444
20	.087	.142	.335	.337	.201	.261	.302	.490
21	.030	.031	.186	.132	.269	.130	.240	.363
22	.146	.024	.345	.171	.155	.193	.209	.906
23	.070	.180	.447	.334	.177	.271	.279	.374
24	.101	.220	.223	.122	.154	.134	.193	.488

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10	.471							
11	.535	.376						
12	.451	.394	.383					
13	.537	.490	.481	.478				
14	.096	.047	.022	.156	.060			

(Contd.)

APPENDIX I (*Contd.*)

	9	10	11	12	13	14	15	16
15	−.004	.166	.023	.208	.031	.174		
16	.322	.321	.231	.457	.336	.091	.461	
17	.280	.189	.163	.427	.291	.165	.129	.228
18	.402	.372	.440	.570	.479	.184	.060	.315
19	.413	.340	.253	.394	.457	−.140	−.153	.273
20	.417	.349	.481	.519	.554	.179	.013	.326
21	.331	.221	.424	.302	.417	.107	−.106	.181
22	.432	.321	.389	.396	.428	.118	.026	.136
23	.429	.323	.343	.464	.404	.161	.003	.300
24	.414	.344	.366	.512	.477	.274	−.020	.237

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18	.493							
19	.334	.405						
20	.330	.603	.354					
21	.190	.413	.283	.407				
22	.298	.378	.274	.371	.315			
23	.387	.542	.423	.551	.362	.395		
24	.276	.334	.276	.378	.390	.277	.206	

APPENDIX J

Principal Component Factors for the 18-19 Age Group

Variable Number	Variable	Factor I	II	III	IV	V	VI	VII
1	Inf	551	−470	158	092	−078	−229	058
2	Comp	447	−320	454	221	288	−115	−118
3	Arith	572	114	036	−111	−334	−475	−130
4	Sim	379	−285	337	236	303	003	352
5	D Sp	156	365	612	−481	−222	−050	077
6	Voc	591	−521	333	168	−088	006	−172
7	D Sy	010	−568	−513	−080	317	035	−159
8	PC	239	235	565	−465	107	280	−133
9	BD	488	353	−296	345	110	−265	−095
10	PA	271	174	089	−338	297	−348	−202
11	OA	359	462	−157	045	331	329	157
12	VR	767	−351	011	−139	−045	098	−097
13	SR	714	283	025	150	223	057	−056
14	CSA	−041	−155	−160	−497	593	−246	−058
15	LU − S	359	−570	−242	−342	−222	152	023
16	LU − G	630	−428	049	−027	−059	317	043
17	NA	446	−005	−519	−256	−224	−233	134
18	AR	597	223	−317	−132	−132	142	−298
19	MR	621	429	030	234	071	−038	−303
20	PM − A	637	215	−109	−058	087	192	138
21	Ser	397	148	−273	053	−086	133	−133
22	Cl	505	142	−240	−235	065	−007	571
23	Mat	500	161	−033	079	−146	266	−020
24	Cond	501	096	112	160	−070	−298	398

Note : Decimal points omitted.

APPENDIX K

Principal Component Factors for the 25-34 Age Group

Variable Number	Variable	Factor						
		I	II	III	IV	V	VI	VII
1	Inf	414	439	−336	−143	−349	−076	340
2	Comp	314	502	021	−116	−157	−005	390
3	Arith	527	−099	−021	−083	217	619	079
4	Sim	445	472	026	314	−068	−302	−054
5	D Sp	272	−029	248	169	601	−222	389
6	Voc	558	472	−269	−205	026	−044	176
7	D Sy	353	−024	729	−112	−077	174	−023
8	PC	739	−099	−061	−427	−106	019	−021
9	BD	695	−202	−047	−222	−012	−002	−244
10	PA	615	−016	−194	−358	190	020	−047
11	OA	643	−185	050	−290	−063	−336	053
12	VR	745	221	−109	151	015	−083	196
13	SR	713	−269	−072	−011	184	−082	−164
14	CSA	259	153	696	−223	−363	034	159
15	LU − S	184	645	272	−136	456	222	−094
16	LU − G	532	474	−020	081	246	−124	−264
17	NA	518	124	−039	401	−330	283	026
18	AR	744	−036	027	273	−127	067	196
19	MR	556	−158	−478	109	034	218	−023
20	PM − A	726	−146	106	198	−042	−095	052
21	Ser	524	−385	150	149	041	−352	049
22	Cl	571	−238	044	−030	015	130	202
23	Mat	682	−146	090	347	−017	190	−067
24	Cond	572	−236	101	−042	−062	−137	−428

Note : Decimal points omitted.

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BIRANCHI NARAYAN PUHAN (b. 1941) did his Psychology Honours and M.A. from Utkal University, and M.A. and Ph.D. from University of Manitoba, Canada. He has worked as Lecturer in Psychology in Nayagarh College, Ravenshaw College, and is currently working as Reader in Psychology at Utkal University. His research interests are measurement and life-span developmental psychology.

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